Rocket First Motion Timing System Report

US ARMY
MATERIEL COMMAND

UNCLASSIFIED

DTIC AD NUMBER

TECOM PROJECT NUMBER
5-CO-YPO-ARC-701
TEST ACTIVITY REPORT NUMBER

FINAL REPORT

Automation and Remote Control Instrumentation Development

ROCKET FIRST MOTION TIMING SYSTEM (RFMTS)

by

BRUCE BUZZO

for

MATERIEL TEST DIRECTORATE
TECHNICAL SUPPORT DIVISION
ENGINEERING SUPPORT BRANCH

U.S. Army Yuma Proving Ground
Yuma, Arizona

March 1992

Period covered: October 1988–October 1990

Prepared for:
U.S. ARMY TEST AND EVALUATION COMMAND
ABERDEEN PROVING GROUND, MD. 21005-5055

DISTRIBUTION
UNLIMITED
APPROVED FOR
PUBLIC RELEASE

UNCLASSIFIED

DISPOSITION INSTRUCTIONS

Destroy this report when no longer needed. Do not return to originator.

DISCLAIMER

Information and data contained in this report is based on inputs available at the time of preparation. Because the results may be subject to change, this document should not be construed to represent the official position of the U.S. Army Materiel Command unless so stated.

The use of trade names in this report does not constitute an a official endorsement or approval of the use of such commercial hardware or software. This report may not be cited for purposes of advertisement.

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS Unclassified
2a. SECURITY CLASSIFICATION AUTHORITY Unclassified	3. DISTRIBUTION / AVAILABILITY OF REPORT Unlimited Distribution Approved for public release
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) YPG report No.	5. MONITORING ORGANIZATION REPORT NUMBER(S) TECOM Project No. 5-CO-YPO-ARC-701
6a. NAME OF PERFORMING ORGANIZATION U.S. Army Yuma Proving Gnd. Engineering Support Br. 6b. OFFICE SYMBOL (If applicable) STEYP-MT-TS	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) Yuma, AZ 85365-9103	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING / SPONSORING ORGANIZATION 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code) Aberdeen Proving Ground, MD 21005-5055	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)
Instrumentation Development Final Report; Rocket First Motion

12. PERSONAL AUTHOR(S)
Bruce Buzzo

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM Oct 88 TO Oct 90	March 1992	58

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The Rocket First Motion system was designed and developed to record the time interval from the firing pulse until the launcher detent is raised due to the forward movement of the rocket.

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT ☐ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL Bruce Buzzo	22b. TELEPHONE (Include Area Code) (602) 328-6131 22c. OFFICE SYMBOL STEYP-MT-TS

DD Form 1473, JUN 86 Previous editions are obsolete. SECURITY CLASSIFICATION OF THIS PAGE

TABLE OF CONTENTS

FOREWORD

This report was prepared in accordance with Draft TECOM Regulation 70-18: Research, Development, and Acquisition for Instrumentation Development and Acquisition, 1 April 1989. It documents the development of instrumentation to record data on the time to first motion for 2.75-inch rockets using the M158 launcher. The project was conducted by the Engineering Support Branch of the Technical Test Services Division at U.S. Army Yuma Proving Ground (YPG) and represents the continuing efforts of YPG to enhance and expand its testing capabilities.

Acknowledgments are given to the following Government and Contractor personnel for their contributions to the project: Cpl. Goodin, Mr. S. Wegge, Mr. G. Stewart, Mrs. M. Wilke, Mr. G. Bauer, Ms. G. Beaubier, and Mr. M. Reed. Special acknowledgments are given to CO-OP student Mr. Timothy Sivertson for the physical layout and assembly of the counter/display and firing pulse circuitry.

SECTION 1: SUMMARY

1.1 BACKGROUND

The U.S. Army Yuma Proving Ground (YPG), Aircraft Armament Engineering Branch, periodically conducts rocket motor tests that require recording the time to rocket first motion to determine whether the rocket motors meet minimum established criteria for safety and performance. In April of 1986, the Aircraft Armament Engineering Branch requested that the Engineering Support Branch develop a method for obtaining rocket first motion data on rocket motors. The Automation and Remote Control Instrumentation Development project was used to develop an automatic instrument for remotely measuring first motion time.

For test purposes, rocket first motion is defined as the time interval from activation of the firing pulse until the rocket motor develops enough thrust to raise the detent device (which retains the rocket in the launcher) high enough to begin forward movement of the rocket.

Recording the time to rocket first motion was considered significant in the areas of safety and performance. The data become especially important for rockets fired from multiple-sequence launchers that can fire at intervals of less than fifty (50) milliseconds (ms). Any substantial delay from one rocket to the next can increase the potential for an accident. Significant variances in launch times also demand that the time required to keep the launcher aimed at a target is increased; this decreases the hit probability.

1.2 DESCRIPTION OF INSTRUMENTATION

The portable RFMTS was designed, developed, manufactured and tested at YPG. It is comprised of four subsystems and a modification to the launcher circuit. The four subsystems are comprised of: the integrated time counter/firing box (firing control box); the firing control safety box (safety box); the motion sensor block; and the signal converter box. All are powered by sealed, rechargeable 12-volt batteries. Refer to Appendix A for a complete parts listing for each subsystem and the modification to the launcher circuit.

The firing control box generates a firing pulse; when it is activated, the current simultaneously fires the rocket and starts the time counters. It accepts the STOP pulses sent from the signal converter box to stop the counters. The redundant output times to first motion are displayed to a resolution of 0.1 ms on two 6-digit Light Emitting Diode (LED) displays located on the front panel of the firing control box.

The safety box is connected in series from the firing control box to the rocket at the launcher. The safety box consists of a momentary fire switch; when actuated, the switch removes the ground from the firing cable and closes the circuit so that the firing pulse can reach the launcher once issued from the firing control box.

The M158A1 launcher wiring was modified to incorporate the RFMTS system. The existing launcher wiring was removed and replaced with RG58 coax cable. The firing-pulse cable was designed so that only one tube is connected to the RFMTS at any given time. A second cable is also atached to the same tube in parallel with the firing-pulse cable. A 1.2-ohm precision resistor is connected in series with the firing current when the cable is connected to the firing control box. This cable is used as a squib test line, and is used for alignment purposes only.

The motion sensor block is attached directly to the launcher tube and is the primary interface between the rocket launcher and the firing control box. Data is collected by both switches without intervention by the operator. The optical switches stop the counters when the rocket motor thrust is high enough to overcome detent spring action (thus allowing forward/first motion of the rocket).

The signal converter box is attached to the launcher mount and is connected in series between the motion sensor block and firing control box. When first motion begins, this unit sends a STOP signal to the counter circuit in the firing control box, where the time to first motion is then displayed.

The four subsystems of the RFMTS were designed to function as an integrated unit. Instrumentation alignment procedures are found in Appendix C; for operational procedures, refer to Appendix D.

1.3 OBJECTIVES

A project to develop automatic, remote, and portable instrumentation to measure the time to first motion for rocket motors (using the M158A1 launcher) was initiated and designated the Rocket First Motion Timing System (RFMTS). This portion of the report covers the final design of the portable RFMTS. Refer to Appendix E for a complete history of the entire project.

The two objectives of the RFMTS instrumentation project were:

a. To develop portable instrumentation in compliance with test procedures and Product Function Specification NOS 504-174-TD-006A for Motor, Rocket, 2.75-Inch, Mark 66 Mods.

b. To develop instrumentation capable of remotely firing rocket motors that propel Mark 40 and Mark 66 rockets using a current-regulated firing pulse of either 1.5 or 3.0 amps and measure the time of first motion for the rocket motors, displaying this time to a resolution of 0.1 ms.

1.4 SUMMARY OF RESULTS

The RFMTS instrumentation was developed at YPG over a two-year period. The testing included both the Mark 40 and Mark 66 rockets in the M158A1 launcher.

The instrumentation development was conducted in two phases.The first phase was to design, develop and test instrumentation capable of withstanding the extreme firing environment. In this phase, the type of components needed and the determination of the optimal position to minimize failures was paramount.

All four RFMTS component/circuit designs were developed and manufactured in-house. Specifically, this involves the following subsystem units: (1) Integrated time counter/firing box (firing control box), (2) Firing control safety box (safety box), (3) Motion sensor block, and (4) Signal converter box.

Two failures occurred during this phase; one was due to false triggering of the counters and the other was caused by battery failure on the signal converter unit.

Flying debris caused one of the two switches to miss recording data twice during the same period.

The second phase was to determine the life expectancy of the optical switch that stops the counter circuit. The optical switch was chosen over several other switches tested because it had been proved to be the most durable and least expensive. Optical switch failures occurred after 2127 and 2343 rockets were fired.

It should be noted that in addition to rocket motor first motion testing, the firing control box has been used as a general-purpose rocket firing box and timer including the firing of ZUNI rockets. In its present configuration, the RFMTS cannot be used to sequence- or ripple-fire rockets.

1.5 ANALYSIS

The incorporation of optical switches increased the durability and reliability of the system. Current data indicates the actual number of firings before optical switch failure is over 2000. Current pricing indicates the optical switches are approximately one-tenth the cost of proximity switches (which are susceptible to failure due to the extreme heat encountered during firing). It should be noted that the Zuni and Mark 40 rockets generate more debris than the Mark 66 rockets; their use will necessitate periodic switch cleaning.

The (non-enclosed, 7-tube) M158A1 launcher was used for testing for rocket first motion data; it allows easy access for instrumentation purposes without major modification. Current Army and Navy launchers are EMI/RFI shielded (enclosed) and are made of much thinner material. Access to these launchers for RFMTS testing is difficult due to the enclosure, and the thinner construction material is not designed for sustained firing; thus, reliability and durability for testing purposes is questionable.

The integrated time counter/firing unit (firing control box), although adequate for RFMTS testing, is still to be considered a prototype. Modifications are being made and will continue to be revised as new requirements are placed upon the unit.

1.6 CONCLUSION

The RFMTS instrumentation has reduced the data collection cost and has proved to be a reliable, accurate and durable method of obtaining rocket first motion data.

The development of RFMTS instrumentation enhanced and expanded YPG capability for acquiring rocket first motion data on rocket motors using the M158A1 launcher. Modifications have been made to the system to fire the ZUNI rockets.

Modification to Navy 2.75-inch rocket launchers will be necessary to accommodate future testing with the RFMTS instrumentation.

1.7 RECOMMENDATIONS

The RFMTS instrumentation is recommended for determining and displaying rocket first motion data for all rocket motor testing. It is recommended that the RFMTS be modified to incorporate the Navy launcher intervalometer mode.

The M158A1 launcher is no longer being manufactured and is in limited supply. It is recommended that further development of this instrumentation be considered for future accommodation of the enclosed rocket launchers currently in the military weapons arsenal, or that a durable, long-life launcher be constructed and approved for use in testing.

SECTION 2: DETAILS OF TASK

2.1 OBJECTIVES

The objectives of the RFMTS instrumentation project were:

a. To develop portable instrumentation that is in compliance with test procedures for rocket first motion of rocket motors using the M158A1 launcher; the instrumentation should be capable of electronically measuring and displaying the time to first motion to a resolution of 0.1 ms.

b. To develop instrumentation that would be in compliance with Product Function Specification NOS 504-174-TD-006A for Motor, Rocket, 2.75 Inch, Mark 66 Mods, capable of firing Mark 40 and Mark 66 rockets using a switchable, current-regulated firing pulse of either 1.5 or 3.0 amps.

2.2 ASSEMBLY

The portable RFMTS was designed, developed, manufactured and tested at YPG. It is comprised of four subsystems and a modification to the launcher circuit. The four subsystems are comprised of: the integrated time counter/firing box (firing control box); the firing control safety box (safety box); the motion sensor block; and the signal converter box. All are powered by sealed, rechargeable 12-volt batteries. Refer to Appendix A for a complete parts listing for each subsystem and the modification to the launcher circuit.

2.2.1 FIRING CONTROL BOX

In the final design, the firing control box generates a current-regulated rocket firing pulse switchable to either 1.5- or 3.0-amp modes. When the safety switch is in the FIRE mode and the firing switch is activated, the pulse simultaneously fires the rocket and starts the time counters. The STOP pulses are sent from the signal converter box (via two optical switches located in the motion sensor block) to stop the counters. The redundant output times to first motion are displayed to a resolution of 0.1 ms on two 6-digit Light Emitting Diode (LED) displays located on the front panel of the firing control box.

Please refer to Figures 2.1 through 2.5 for the physical layout and schematic of this subsystem. The firing control box is made up of the following three units:

a. Power Supply/Battery Charger: The power source for the instrumentation system is provided by three 12-Vdc rechargeable batteries. The system uses two batteries in series to produce a 24-Vdc output. The third battery is installed as a backup. The batteries can only be recharged off-line; this is accomplished in the firing box by using a trickle charge, which avoids possible battery damage. The fully-charged

batteries allow independent operations for up to 8 hours. The physical layout and schematic illustrations are presented in Figures 2-1 and 2-2 respectively.

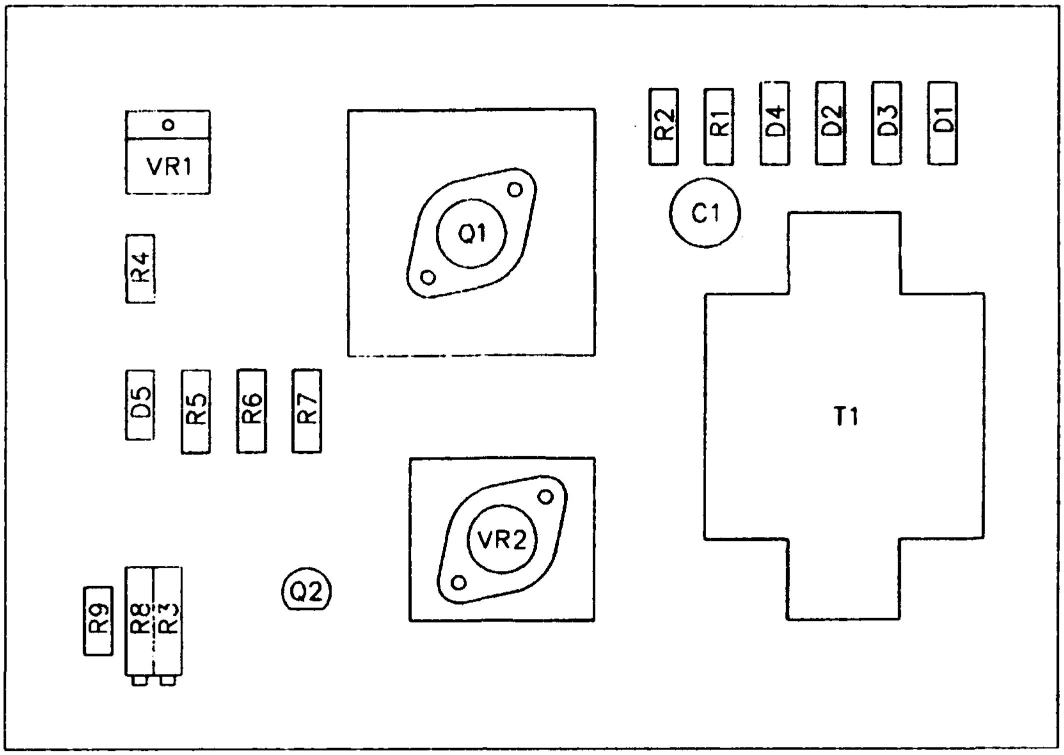

Figure 2-1, Firing Control Box Physical Layout

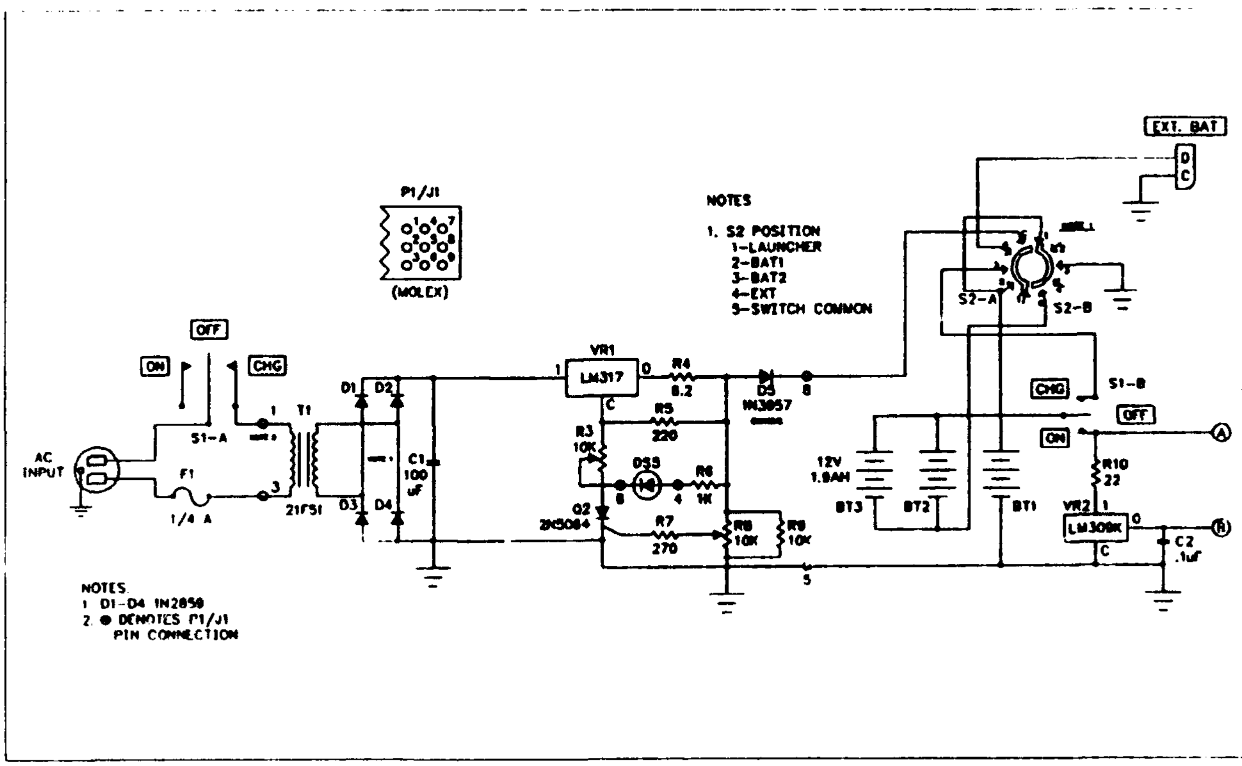

Figure 2-2, Power Supply and Battery Charger Schematic

b. Firing Pulse Generator: The firing pulse generator circuit produces the current-regulated firing pulse signal which is sent to the rocket motor. The physical layout and schematic illustrations for this function are presented in Figure 2-3.

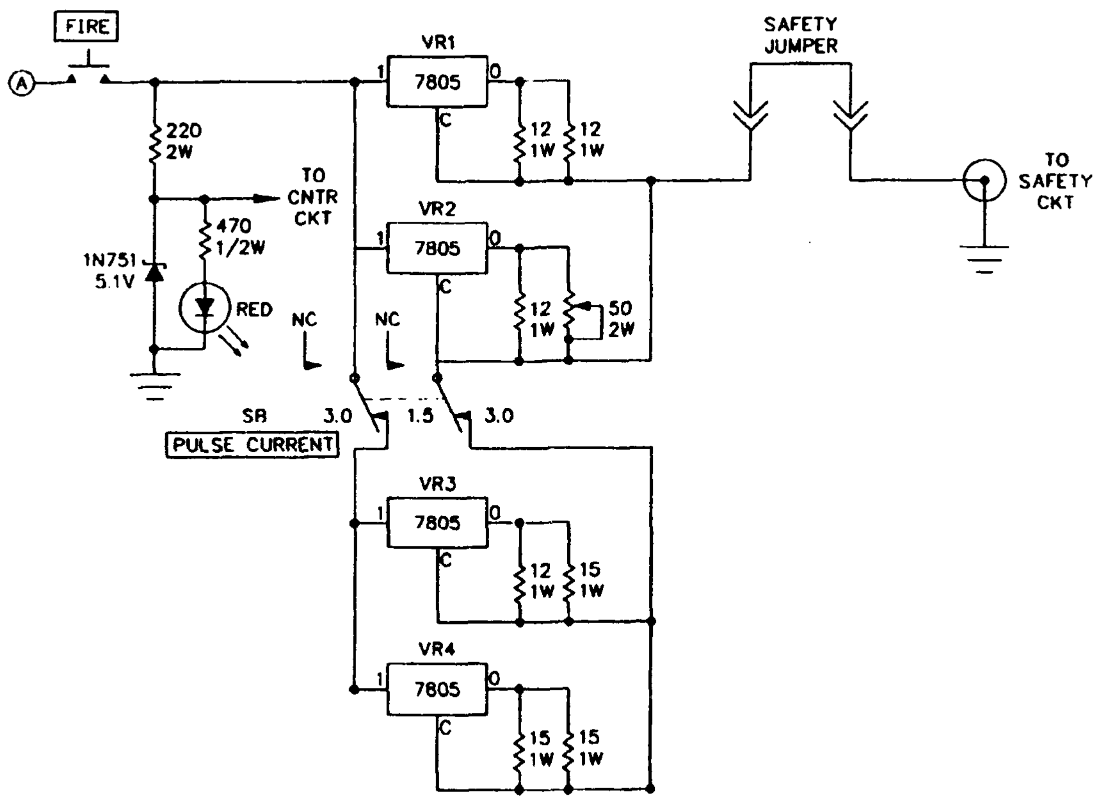

Figure 2-3, Firing Pulse Generator Schematic

c. Time Counter Circuit: The time counter circuit starts and stops the timing, and controls the time displays on an LED read-out. The physical layout for the Time Counter is presented in Figure 2-4; the schematic illustration is divided into two sheets, which are presented in Figures 2-5-A and 2-5-B.

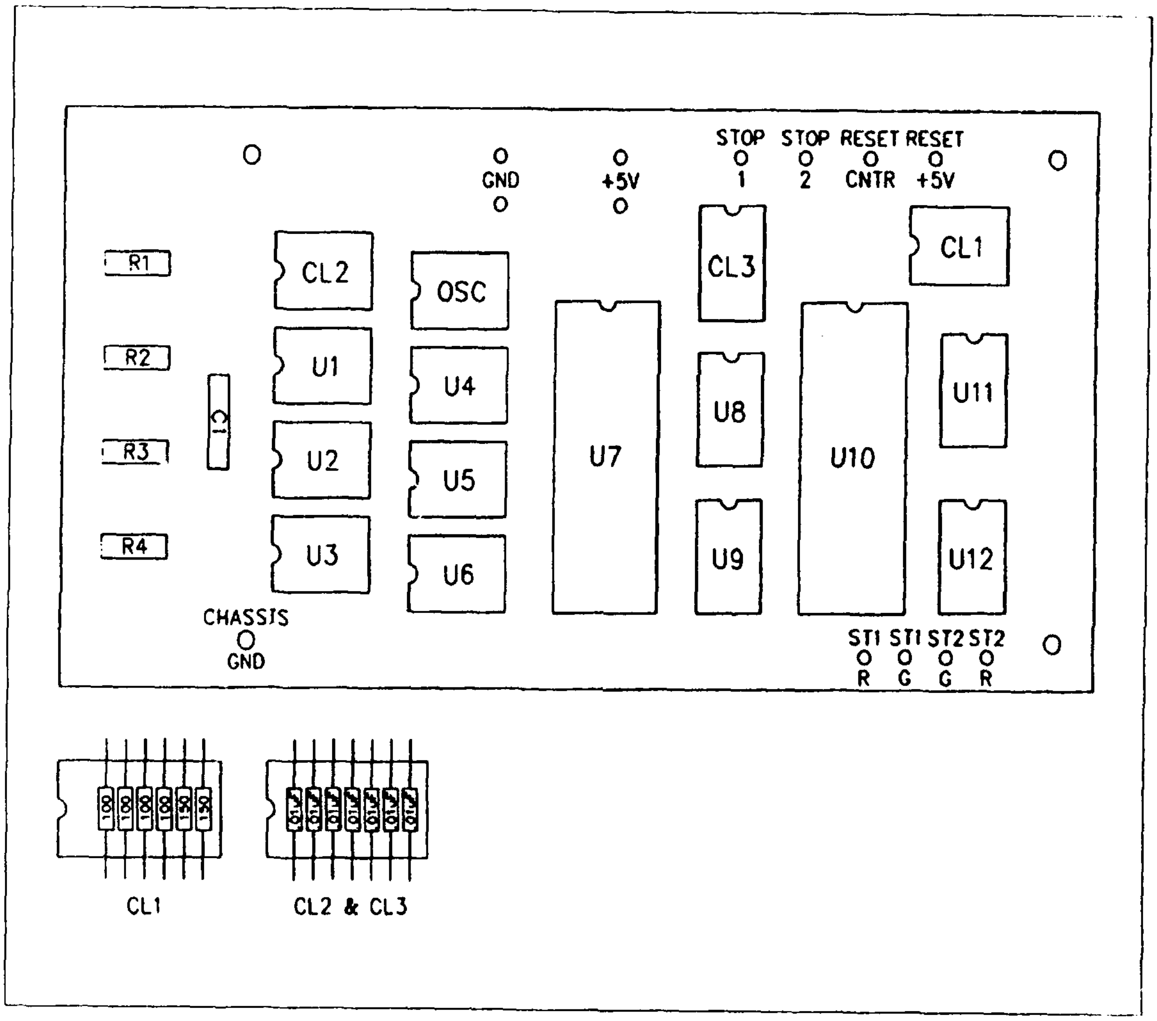

Figure 2-4, Counter Circuit Physical Layout

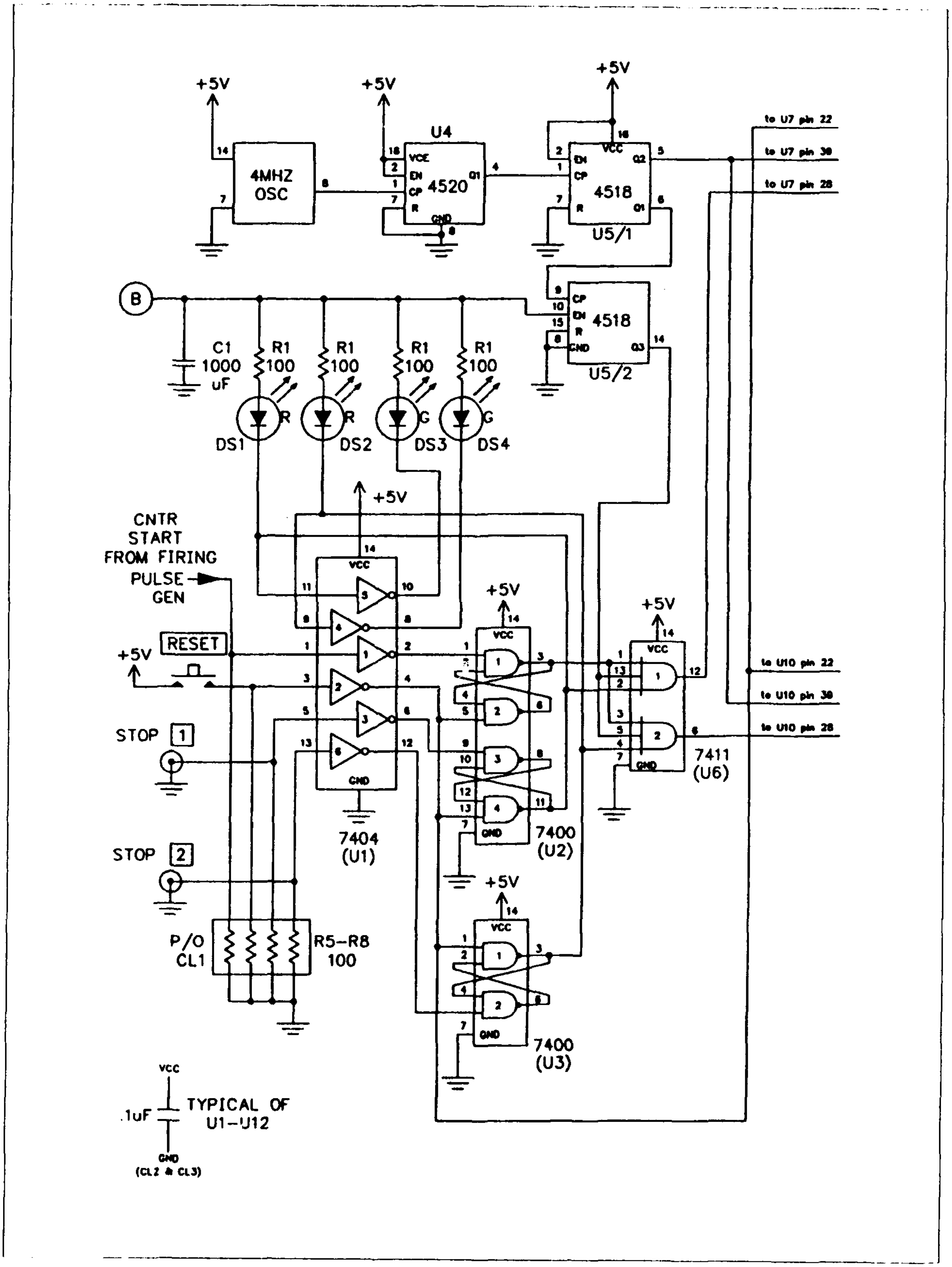

Figure 2-5-A, Counter Circuit Schematic–Sheet 1

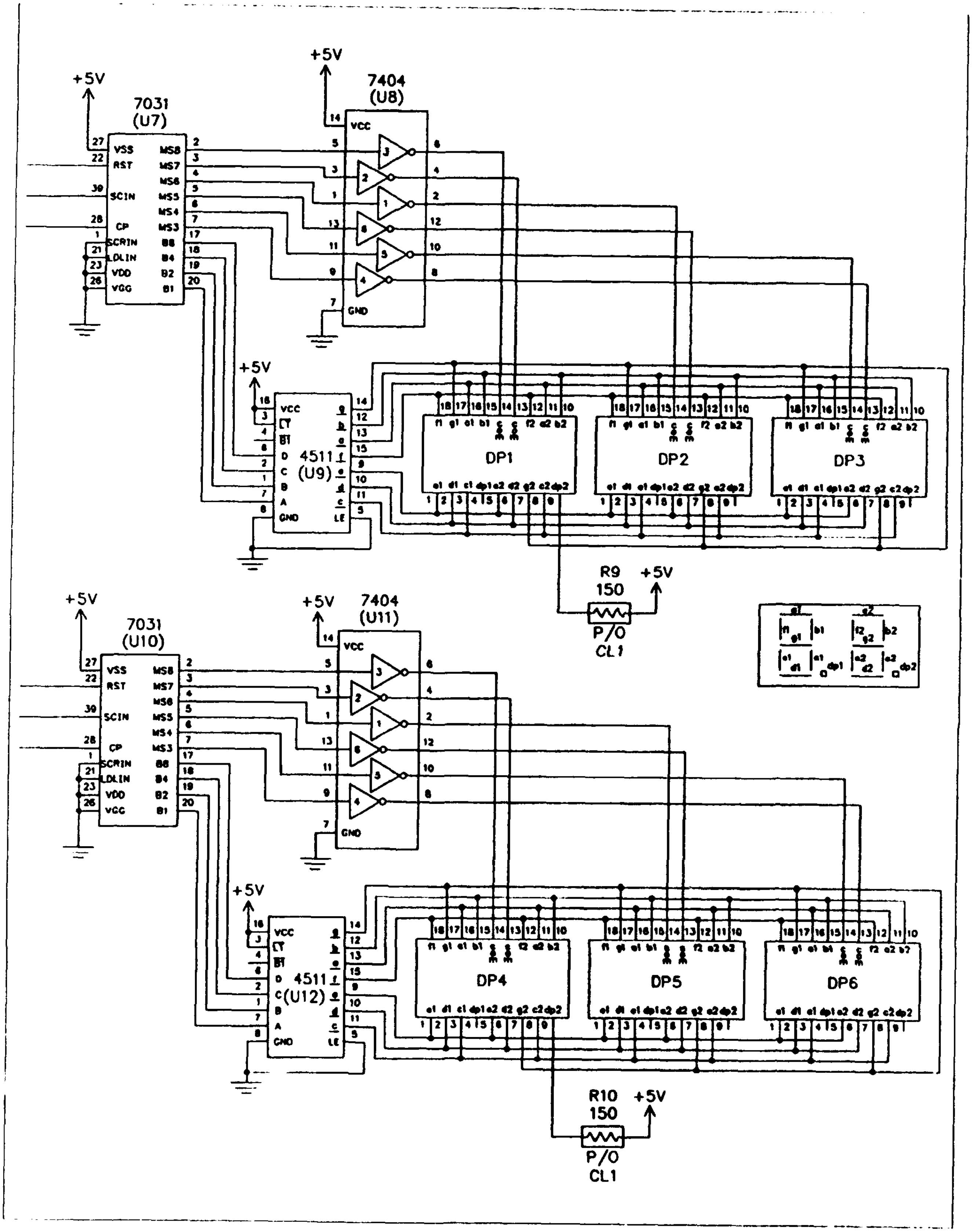

Figure 2-5-B, Counter Circuit Schematic–Sheet 2

2.2.2 *SAFETY BOX*

The safety box is connected in series from the firing control box to the rocket at the launcher via the firing coaxial cable. The Safety Box consists of a momentary FIRE/SAFE switch; in its normal (un-actuated) mode, it keeps the firing coaxial cable at ground potential to the launcher and opens the firing coaxial cable to the firing control box. An operator, usually a person other than the one firing the rocket, manually operates the switch on the safety box. When actuated, the switch removes the ground from the firing cable and closes the circuit so that the firing pulse can reach the launcher once issued from the firing control box. The schematic illustration for the function of the safety box is presented in Figure 2-6.

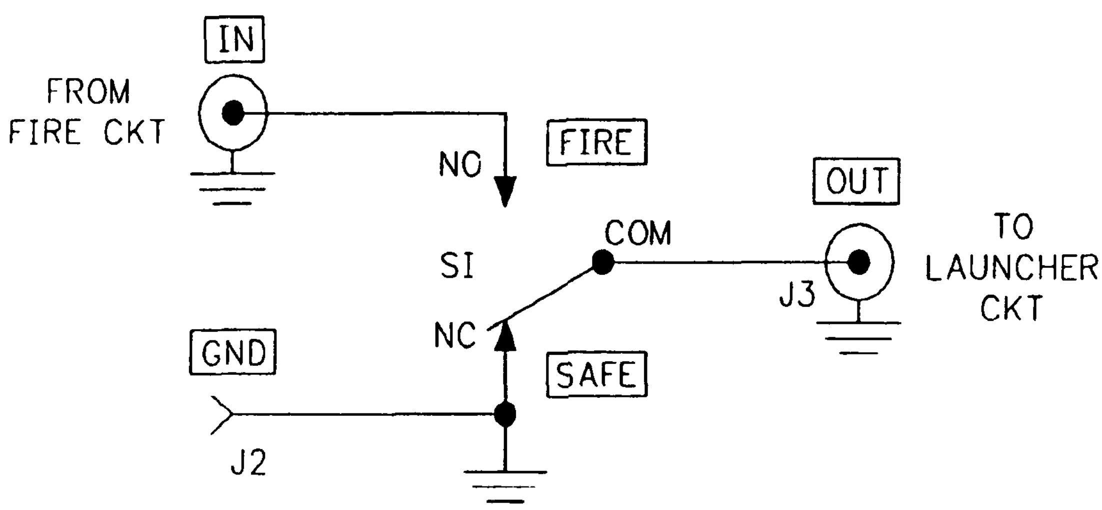

Figure 2-6, Safety Circuit Schematic

2.2.3 *MOTION SENSOR BLOCK*

The motion sensor block is attached directly to the launcher tube and is the primary interface between the rocket launcher and the firing control box. Coaxial cables are employed for this interface. Due to the extreme heat and amount of debris encountered during firing, two switches are used; they act as on-line backup for each other. Data is collected by both switches without intervention by the operator. When properly aligned, a time of activation difference between switches of less than 0.5 ms can be attained. The switches are actuated via a mechanical lever resting on the launcher detent.

The optical switches stop the counter when the rocket motor thrust is high enough to

overcome detent spring action (thus allowing forward/first motion of the rocket). The time to first motion is then displayed on the firing control box. The schematic illustration for the motion sensor block is presented in Figure 2-7.

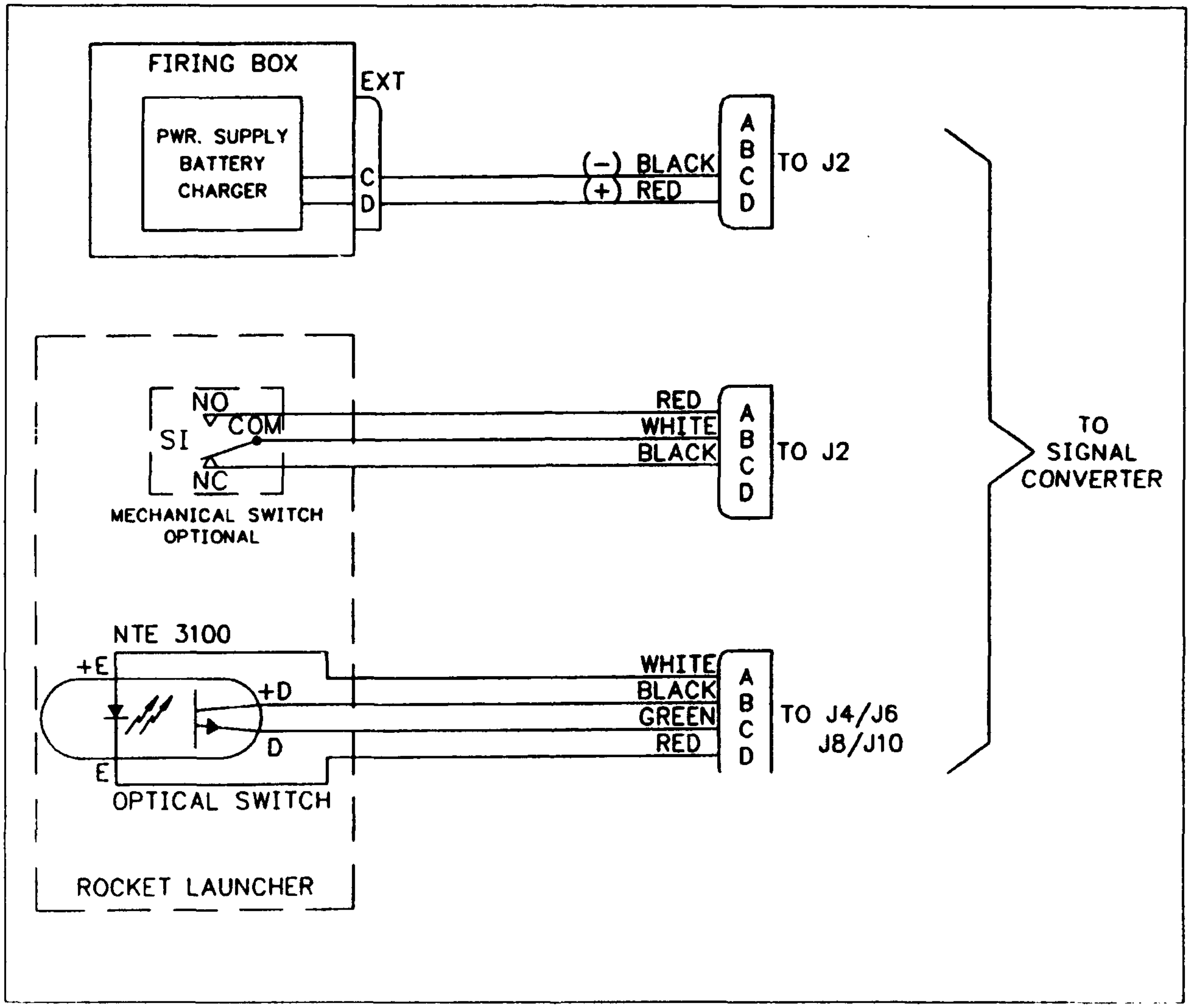

Figure 2-7, Motion Sensor Block Schematic

2.2.4 *SIGNAL CONVERTER BOX*

The signal converter box is connected in series via coaxial cable between the motion sensor block and firing control box; it is a small battery-powered unit that is attached to the launcher mount during firing.

When first motion begins, this unit sends a STOP signal to the counter circuit in the firing control box. The signal converter box takes small analog voltages from two optical switches located in the motion sensor block and converts them to a transistor to transistor logic (TTL) level. The TTL signals are sent to the firing control box via signal coaxial cable

to stop the counters. The physical layout and schematic illustrations for the signal converter box are presented in Figures 2-8 and 2-9 respectively.

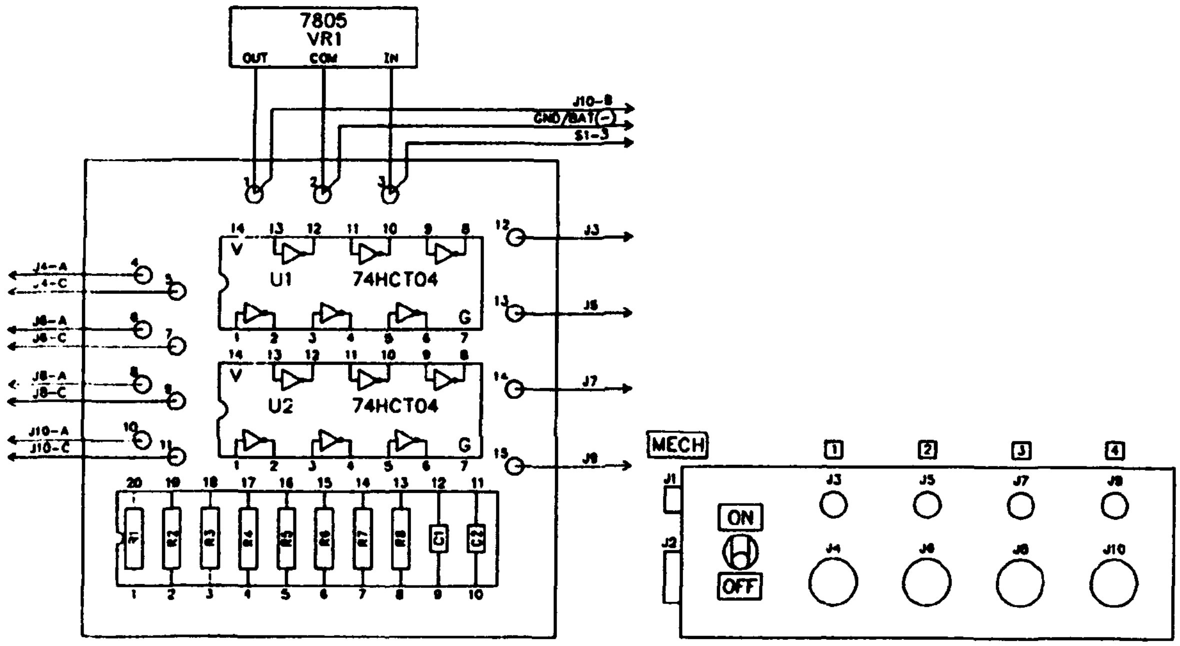

Figure 2-8, Signal Converter Box Physical Layout

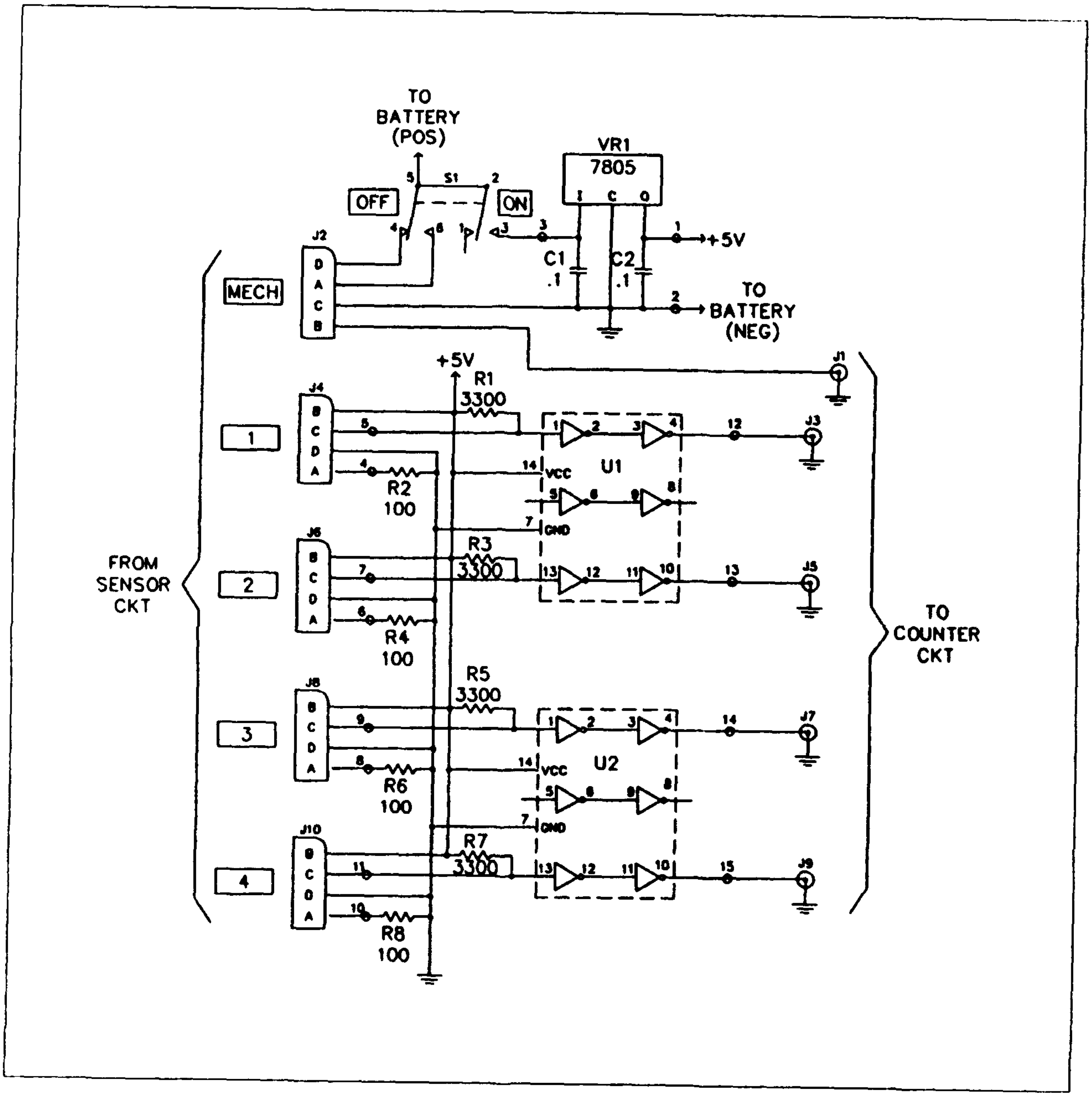

Figure 2-9, Signal Converter Box Schematic

2.2.5 *LAUNCHER CIRCUIT*

The firing-pulse cable was designed so that only one tube is connected to the RFMTS at any given time. A second cable is also atached to the same tube in parallel with the firing-pulse cable. A 1.2-ohm precision resistor is connected in series with the firing current when the cable is connected to the firing control box. This cable is used as a squib test line, and is used for alignment purposes only. The schematic illustration for the launcher circuit is presented in Figure 2-10.

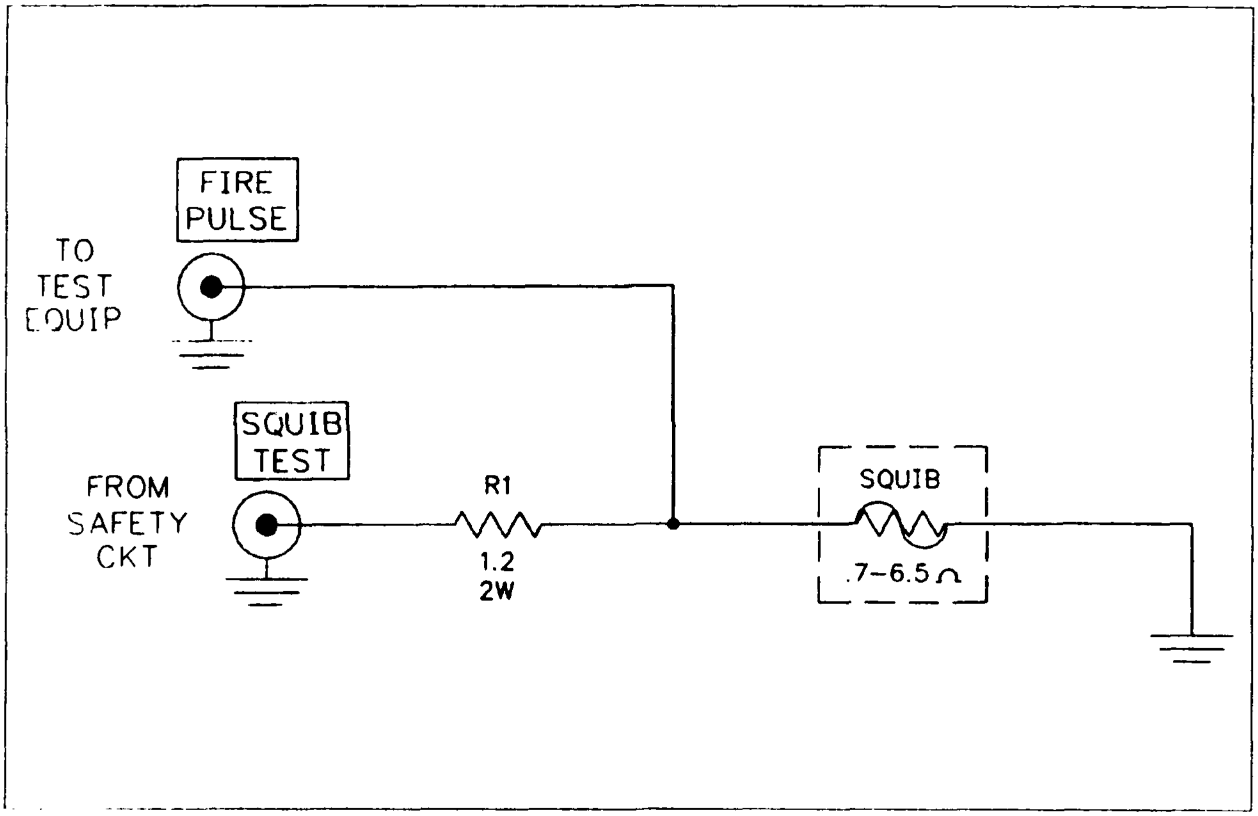

Figure 2-10, Launcher Circuit Schematic

2.2.6 *INTEGRATION OF COMPONENTS*

The four RFMTS subsystems and the modified launcher circuit were designed to function as an integrated unit. Photographs of the four subsystems are shown in Figures 2-11 and 2-12. Please refer to Appendix C for instrumentation alignment procedures and Appendix D for operational procedures.

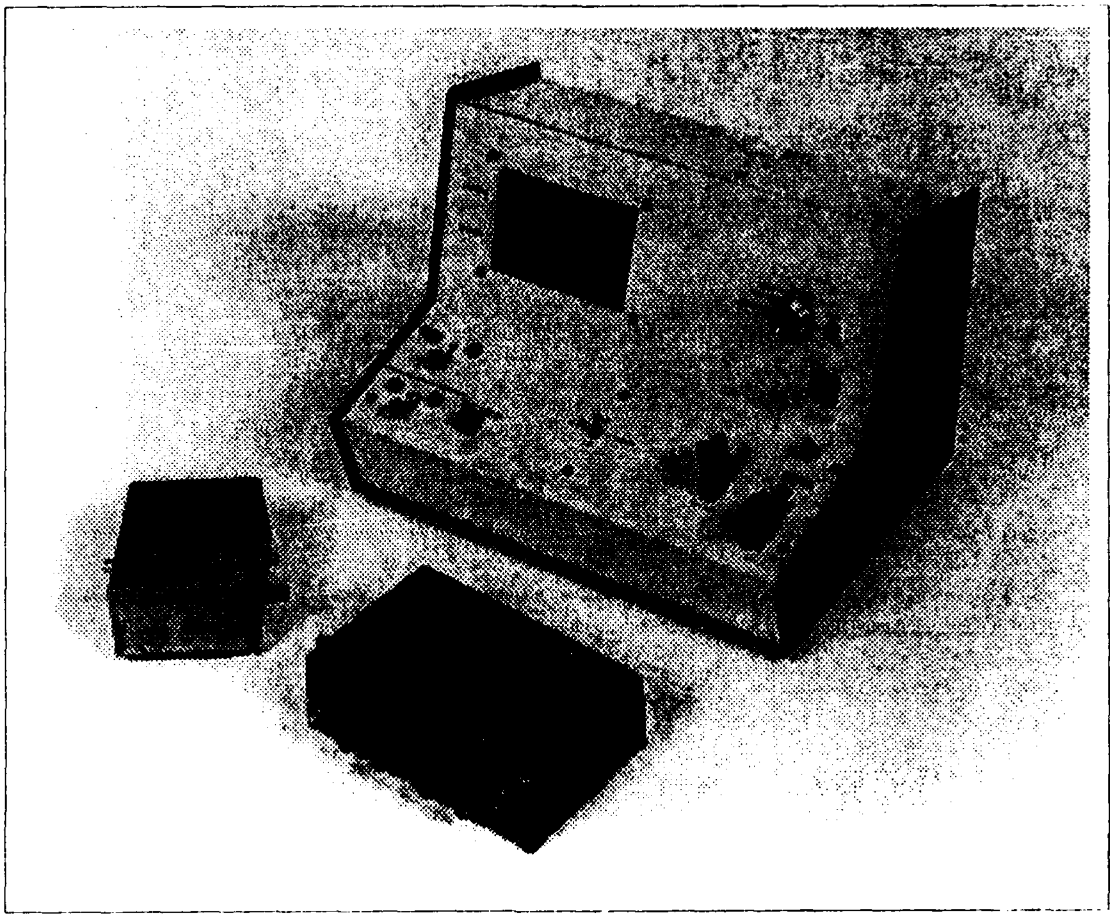

Figure 2-11
Integrated Time Counter/Firing Box (top), Safety Box (left), Signal Convertor Box

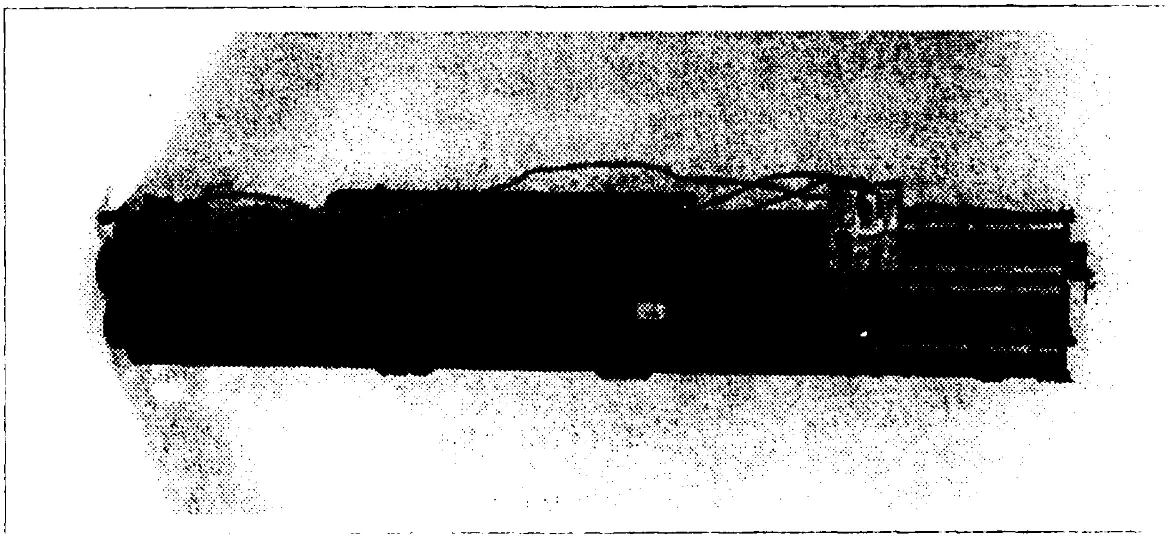

Figure 2-12, Motion Sensor Block (mounted on launcher tube)

2.3 *APPLICATION OF THE INSTRUMENTATION*

The prototype RFMTS instrumentation was used for over two years at YPG for rocket motor tests requiring first motion data. The testing included both the Mark 40 and Mark 66 rockets fired by the M158A1 launcher, and used both the 1.5- and 3.0-ampere firing modes. The RFMTS provided a complete record of times to first motion during this testing.

Developmental testing was conducted simultaneously with with on-going rocket tests.

2.4 *RESULTS OF TEST*

The first test phase was conducted to determine the optimal position of the RFMTS components to minimize failures. During developmental testing, proximity switches, mechanical switches and Hall-effect switches were all used in the sensor block, but were rejected for various reasons. Specifically, Hall-effect and proximity switches failed due to heat; both were high-cost factors as well. Mechanical switches would not stay aligned after 3 to 5 firings, and constantly needed adjustments. The optical switches proved to be the most durable and least expensive of the switches tested. In this phase, the optical switches were not tested to failure, but were rather changed out and/or cleaned on a random basis.

After firing approximately 400 rockets, the sensor block was moved forward of the detent device due to heat and debris created at the rear of the launcher by the Mark 40 rockets. After the move, approximately 570 rounds were fired without any cleaning of the switches. Data was lost twice in 3000 Mark 40 and Mark 66 rocket firings, once due to false triggering of the counters and once due to battery failure on the signal converter unit. Twice during the same period, one of the two optical switches failed to record data due to flying debris; these incidents were not heat related. The actual number of firings which can be attained before switch failure has not yet been established with the senor unit forward of the detent.

The second test phase was to determine the life expectancy of the optical switches. The actual number of firings which can be obtained before failure has many variables involved, such as the type of rocket, frequency of fire, and weather conditions. The first two optical switch failures occurred after 2127 and 2343 rockets were fired; both the Mark 40 and the Mark 66 rocket motors were under test during that period of time. The optics on these switches were cleaned only once, after 1071 rocket firings.

By employing two counters, the times do not differ more than 0.3 ms; problems are mainly due to mechanical inequalities. When properly aligned, a difference of less than 0.1 ms can be attained.

The final designs of the firing control box, thefiring control safety box, the sensor block, and the signal converter box all functioned satisfactorily, as did the modified launcher circuit.

2.5 ANALYSIS

The RFMTS instrumentation was tested using the M158A1 launcher. This particular launcher was chosen because it is not EMI/RFI shielded (enclosed). Thus, access to the launcher detent and igniter arm was allowed. Another consideration was the launcher tubes; the M158A1 launcher tubes are made of heavier-gauge material and are anticipated to have a longer life expectancy than others available.

The development of the RFMTS instrumentation enhanced and expanded the data collection ability for rocket first motion data acquisition. The instrumentation functioned to the satisfaction of the Aircraft Armament Engineering Branch.

The RFMTS instrumentation meets the requirements of NOS 504-174-TD-006A for testing of 2.75-inch rockets.

At the present time, the optical switches cost $2.50 each; at the current switch failure rate, it will cost $5.00 per 2,000 rounds for these parts.

The RFMTS firing box, although adequate for rocket first motion testing, is still to be considered a prototype. Modifications will be made as new requirements are placed upon the unit.

Current design precludes the RFMTS from being used with EMI/RFI (enclosed) Navy launchers or launchers that incorporate the on-board intervalometer. The RFMTS cannot support the EMI/RFI Navy launcher without extensive modification to the tubes. The on-board intervalometer scenario would require extensive modification to the RFMTS power supply.

2.6 CONCLUSIONS

The RFMTS instrumentation has enhanced and expanded the capability of collecting first motion data on the rocket motor. The instrumentation has reduced the cost of the data collection process and provided an accurate, reliable, and durable method of obtaining required data.

2.7 RECOMMENDATIONS

The RFMTS instrumentation is recommended for determining time to rocket first motion in testing of all HYDRA- 70 rockets using the M158A1 launcher.

It is also recommended that further development of this instrumentation be considered for future accommodation of the enclosed rocket motor launchers currently in the military weapons arsenal or that a durable, long-life launcher be constructed and approved for use in first motion testing.

APPENDIX A: PARTS LIST

The parts used in the assembly of the components of the Rocket First Motion Timing System (RFMTS) are listed below.

A-1. Power Supply/Battery Charger (Figure 2-2):

Quantity	Nomenclature	Description
3	Battery	Power Sonic, 12-volt, 1.9-amp hour, PS1219
1	Connector, receptacle	Singatron, ac power, AC-008
1	Connector, receptacle	Molex, 9-pin, size 0.093
1	Connector, plug	Molex, 9-pin, size 0.093
1	Connector	Bendix, MS3112E-8-4S
1	Capacitor, electrolytic	0.1-UF, 25-Vdc
1	Capacitor, electrolytic	100-UF, 50-Vdc
4	Diode	IN2859
1	Diode	IN3957 or IN4004
1	Fuse	1/4-amp, 25O-V, 3AG, slow blow
1	Fuse holder	3AG
1	Resistor	6.2-ohm, 1/4-W
1	Resistor	22-ohm, 1-W
1	Resistor	220-ohm, 1/4-W
1	Resistor	270-ohm, 1/4-W
1	Resistor	1K-ohm, 1/4-W
1	Resistor	10K-ohm, 1/4-W
1	Resistor	Variable 10K-ohm

Power Supply/Battery Charger (continued):

Quantity	Nomenclature	Description
	SCR	2N5064 or NTE5404
1	Switch, toggle	Arrow Hart, DPDT (on-off-on), 82609
1	Switch, rotary	2-pole, 5-position, PA1003
1	Transformer	21F51
1	LED, yellow	34165-LED-440Y
1	Vector board	4- x 6-inch
1	Voltage regulator	+5-V, 3-terminal, (LM309K)
1	Voltage regulator	Variable 3-terminal, (LM317)
1	Terminal strip	7-terminal
1	Transistor socket	TO-3 type
1	Heat sink	TO-3 type
As needed	wire	22 AWG

A-2. Firing Pulse Generator (Figure 2-3):

Quantity	Nomenclature	Description
1	Connector, BNC Jack	Amp 658, bulkhead mount
1	Diode, Zener	1N751
1	LED, red	34165-LED-440R
1	Binding post, dual	Banana jack, panel mount
4	Resistor	12-ohm, 1/2-W
3	Resistor	15-ohm, 1/2-W

Firing Pulse Generator (continued):

Quantity	Nomenclature	Description
1	Variable resistor	50-ohm, 2-W potentiometer, RV4LAYSD500A
1	Switch	MS35058-26, MIL-S-83731
1	Guard	MS25224-3, MIL-G-7703
1	Switch, toggle	DPST, MS75029-23
1	Resistor	470-ohm, 1/2-W
1	Resistor	220-ohm, 1/2-W
4	Voltage regulator	5-V, 3-terminal, 7805 (LM340T05)

A-3. Counter Circuit (Figure 2-5-A and 2-5-B):

Quantity	Nomenclature	Description
12	Capacitor	0.1-UF
1	Capacitor, electrolytic	1000-UF, 50-Vdc
1	Crystal OSC	Digi-key, 4.0-MHz
2	IC	MC14511
1	IC	MC14518
1	IC	MC14520
2	IC	7031
2	IC	74HCT00
3	IC	74HCT04
1	IC	74LS11
2	LED, green	34165-LED-440G

Counter Circuit (continued):

Quantity	Nomenclature	Description
2	LED, red	34165-LED-440R
6	LED display	Digi-key, 2-digit, LN526RK
4	Resistor	100-ohm, 1/2-W
4	Resistor	100-ohm, 1/4-W
2	Resistor	150-ohm, 1/4-W
2	Connector, BNC	Amp-658, bulkhead mount
1	Switch, push-button	Jim-pak 35-412 (normally open)
2	Vector Board	4-x 8-inch
As needed	Wire wrap IC sockets	AWG 30

A-4. Safety Circuit (Figure 2-6):

Quantity	Nomenclature	Description
2	Connector, non-insulated	BNC jack, bulkhead mount
1	Connector	Binding post 5-way (black), PN 111-0103-001
1	Switch, toggle	MS35058-26 MIL-S-83731 SPST
1	Guard	MS25224-3 MIL-G-7703
1	Chassis box	Bud, CU-234
As needed	Wire	22 AWG

A-5. Motion Sensor Block (Figures 2-7 and A-1 through A-8):

Quantity	Nomenclature	Description
1	Sensor mount	Local fabrication (For complete drawings, please refer to Figures A-1 through A-8. The complete parts list for numbered items in Figure A-8 begins on page A-14.)
2	Connector	MS 3116F-8-4S
As needed	Cable	Belden, No. YR22512

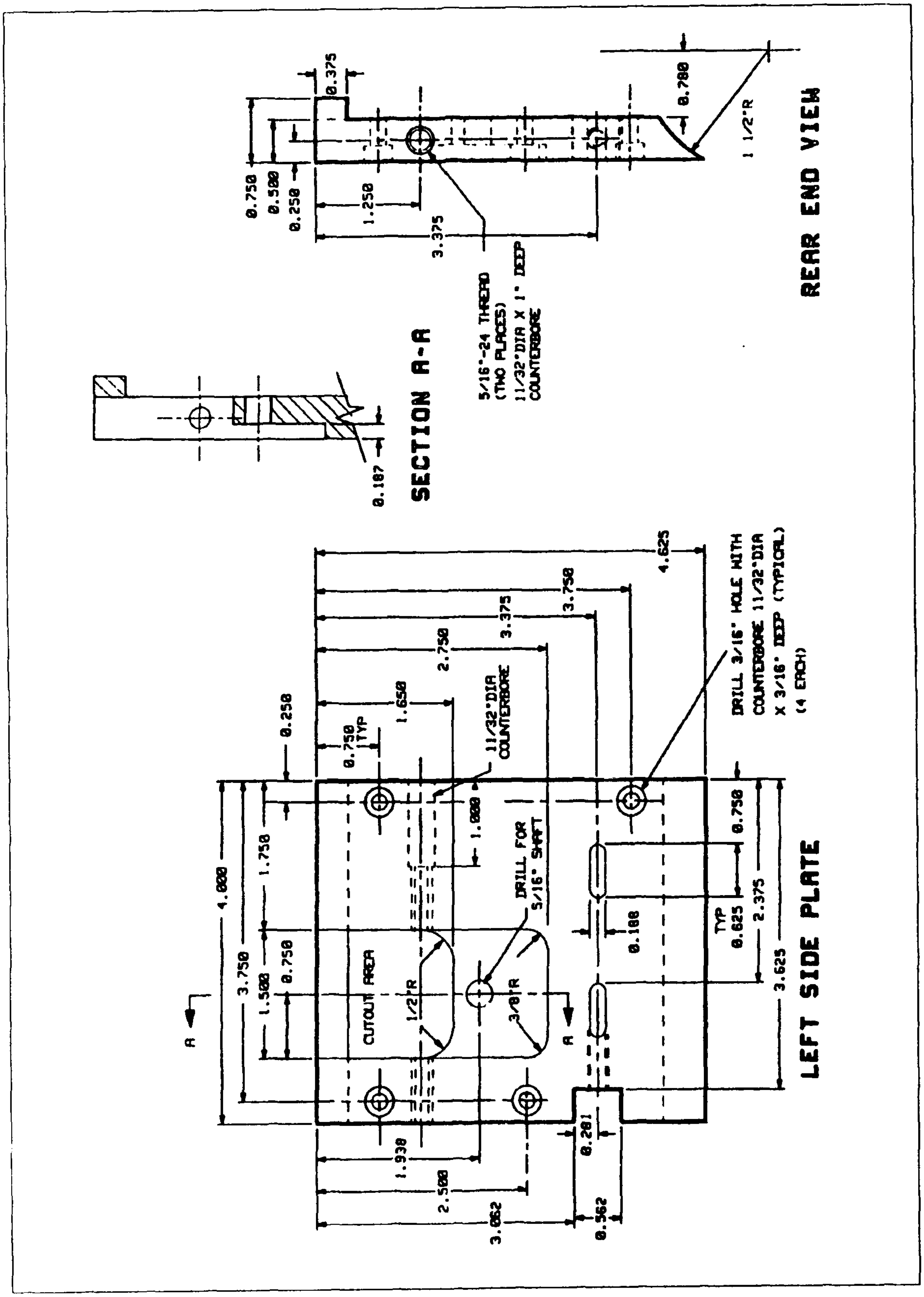

Figure A-1, Motion Sensor Block Diagram, Sheet 1

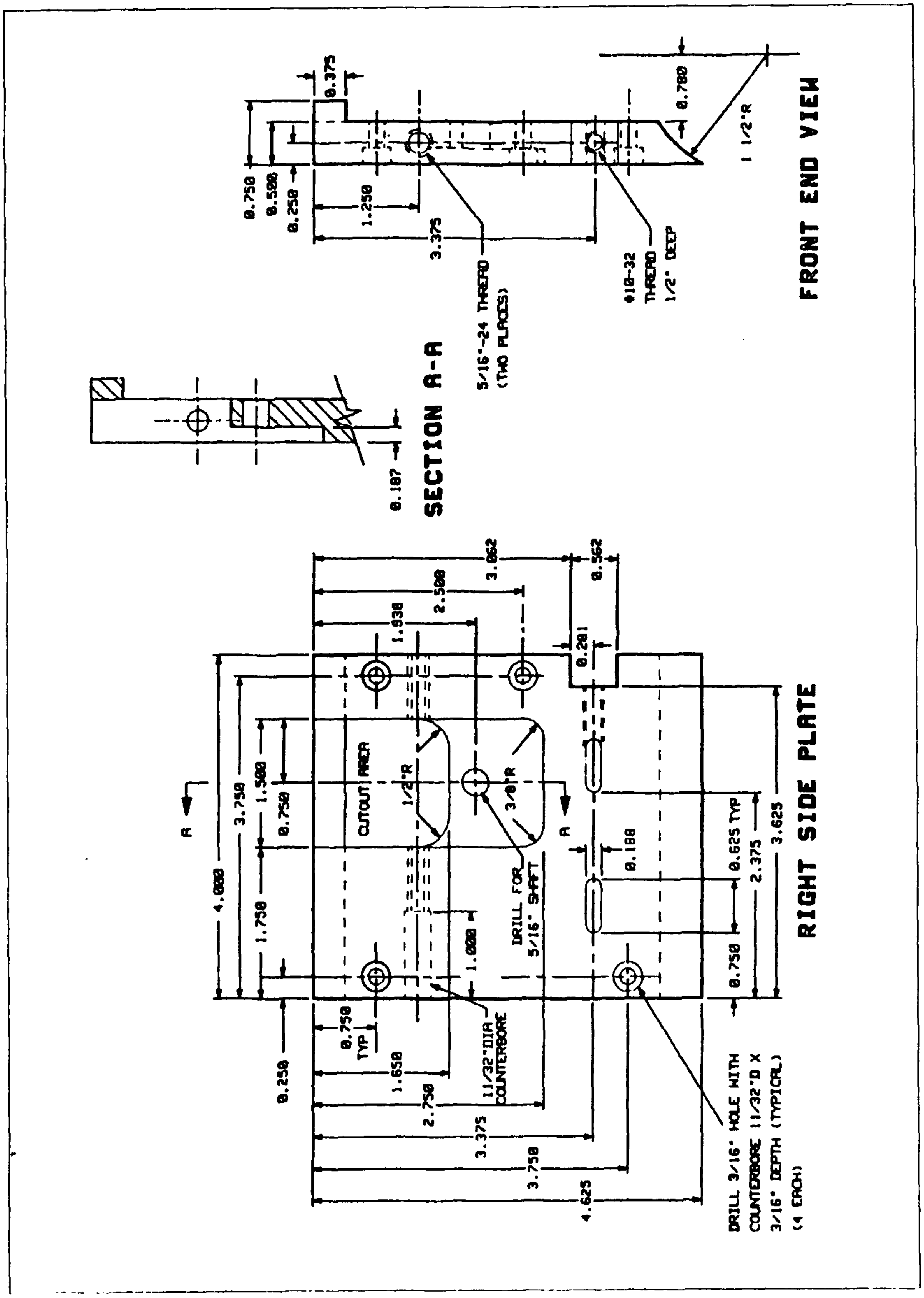

Figure A-2, Motion Sensor Block Diagram, Sheet 2

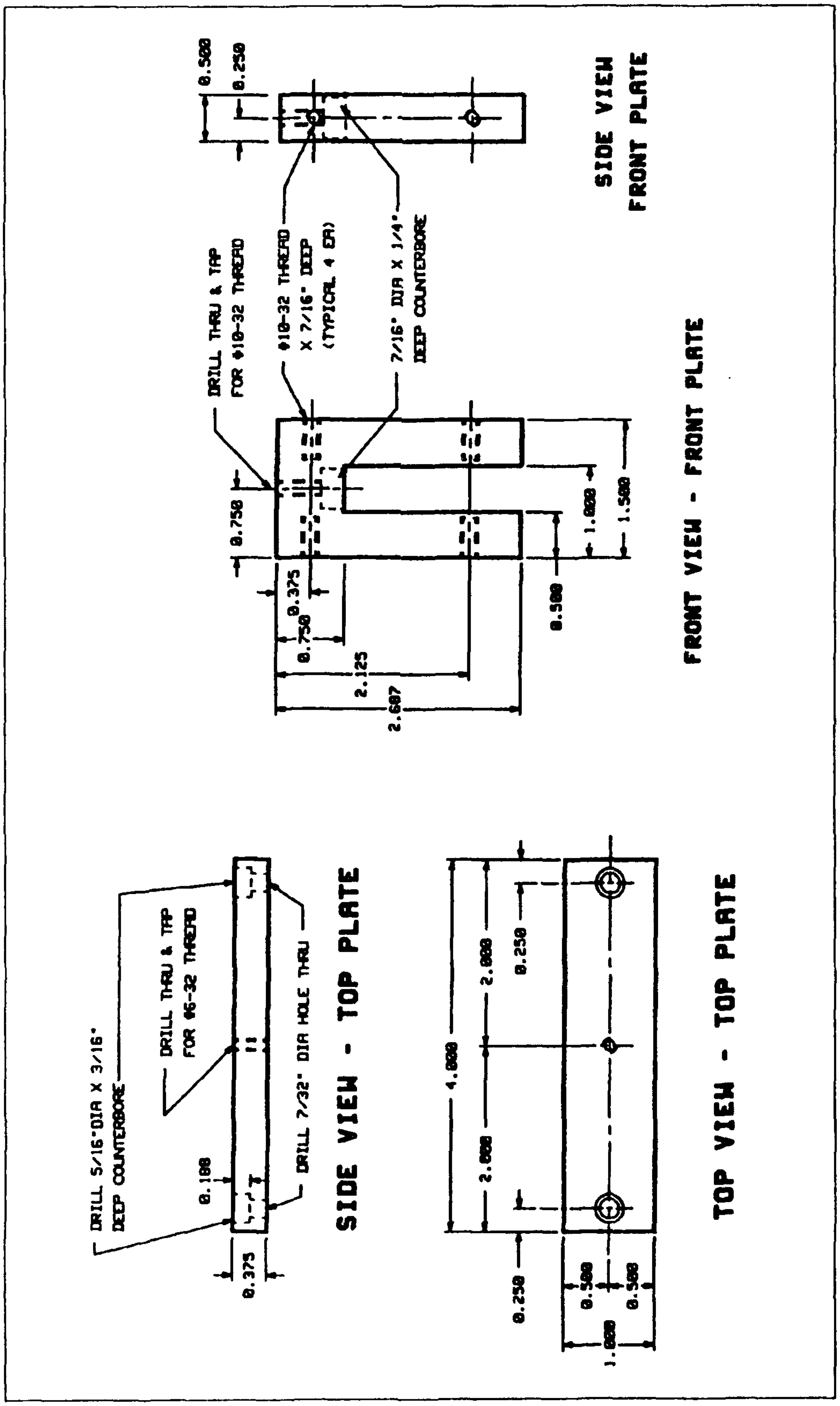

Figure A-3, Motion Sensor Block Diagram, Sheet 3

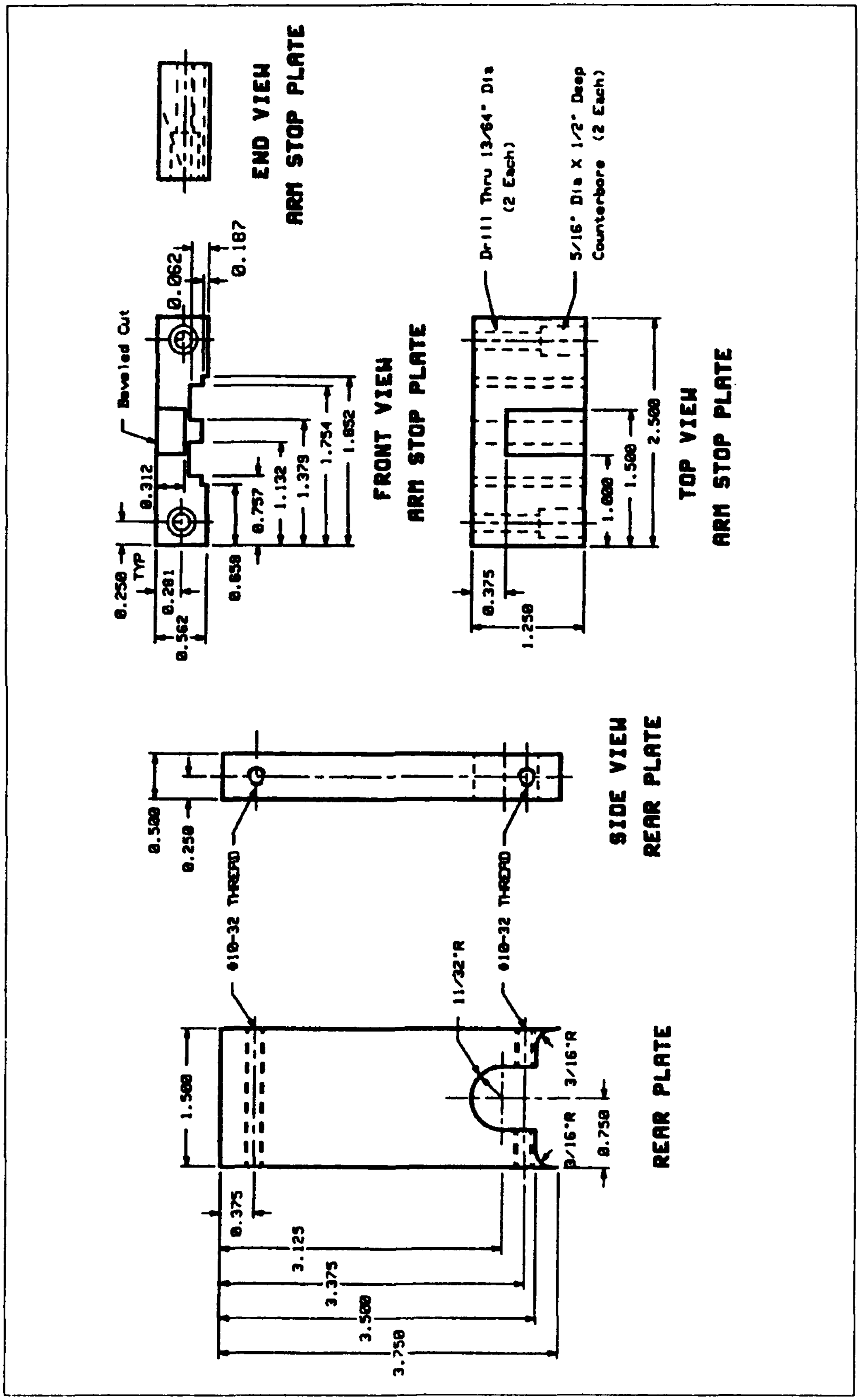

Figure A-4, Motion Sensor Block Diagram, Sheet 4

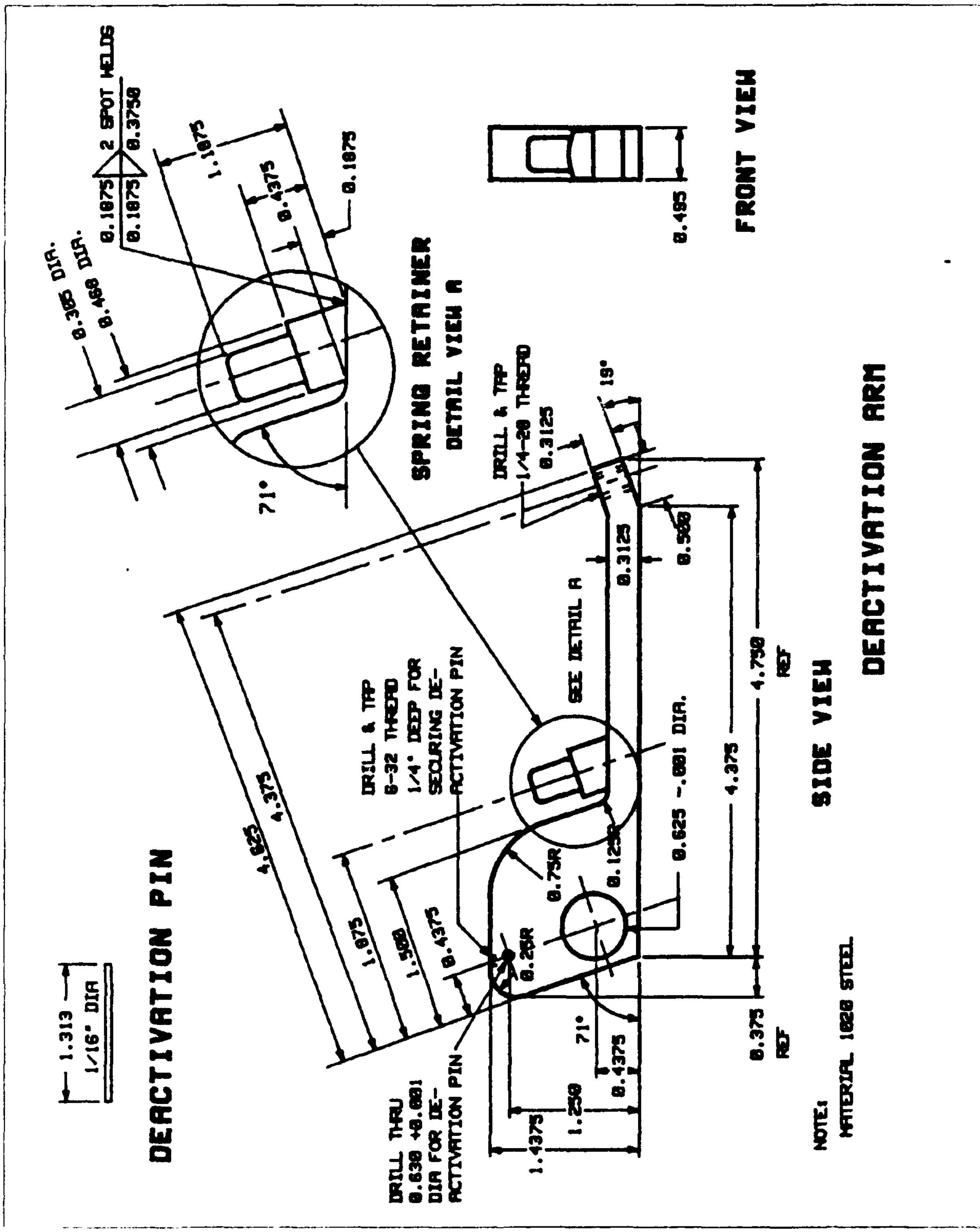

Figure A-5, Motion Sensor Block Diagram, Sheet 5

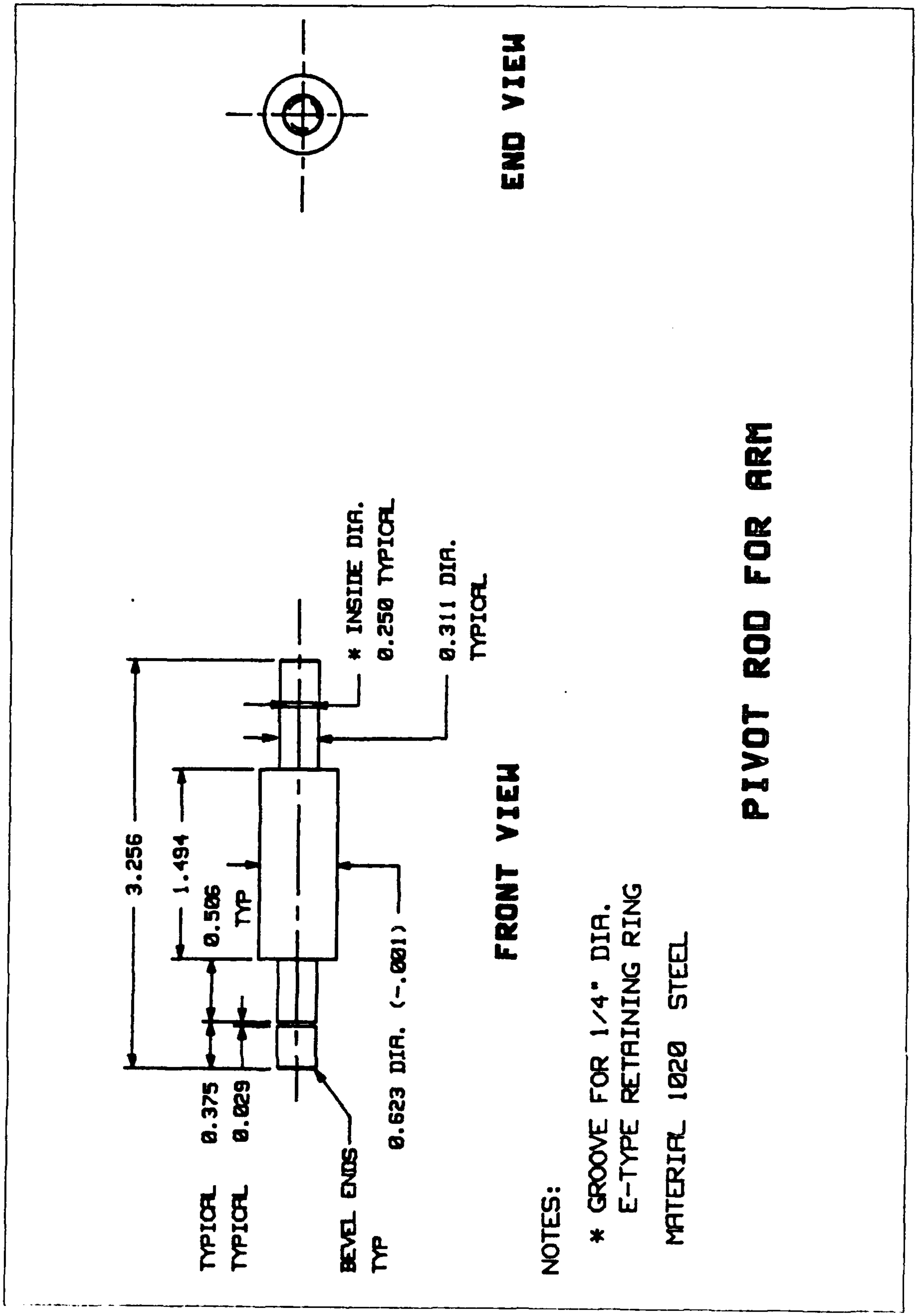

Figure A-6, Motion Sensor Block Diagram, Sheet 6

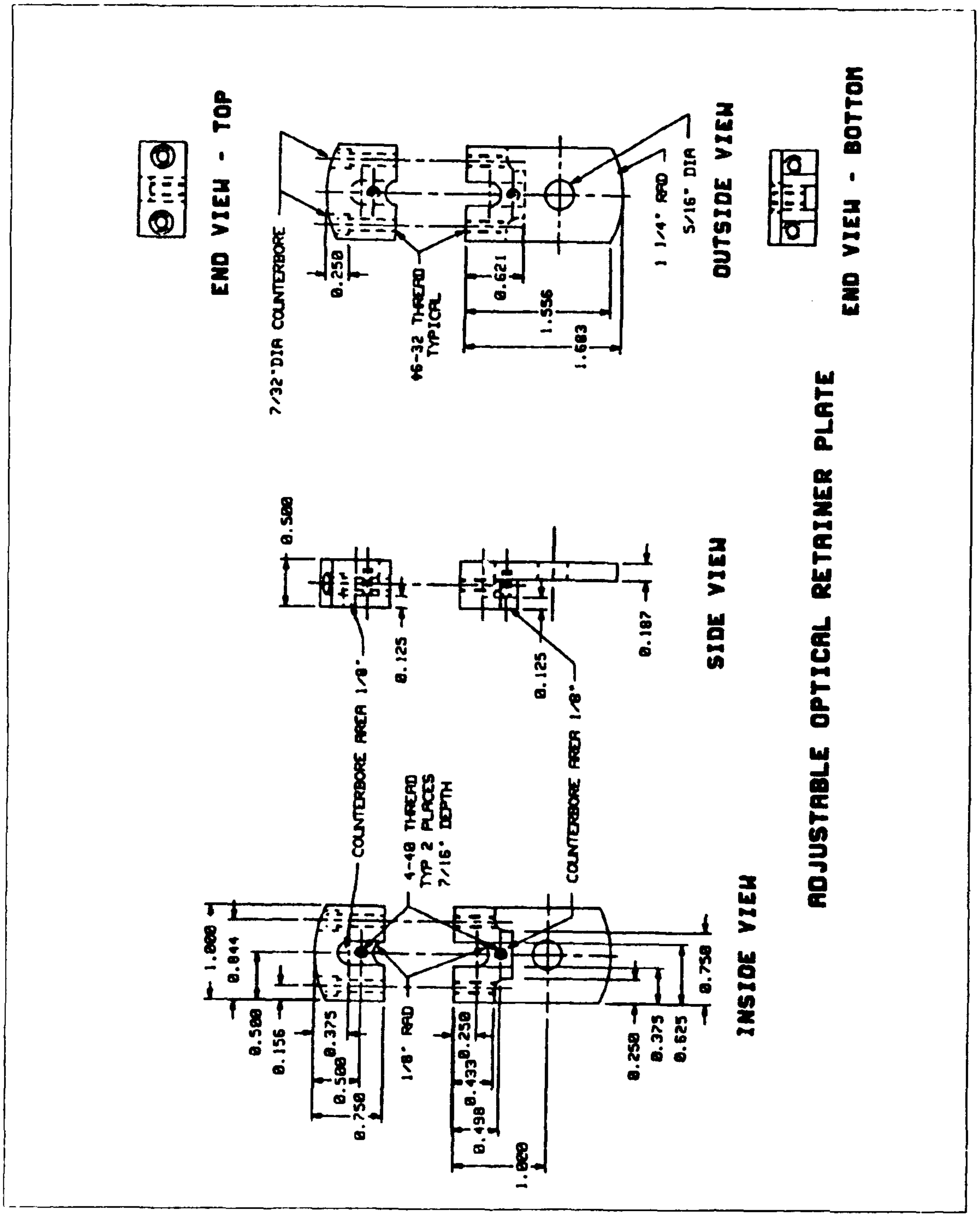

Figure A-7, Motion Sensor Block Diagram, Sheet 7

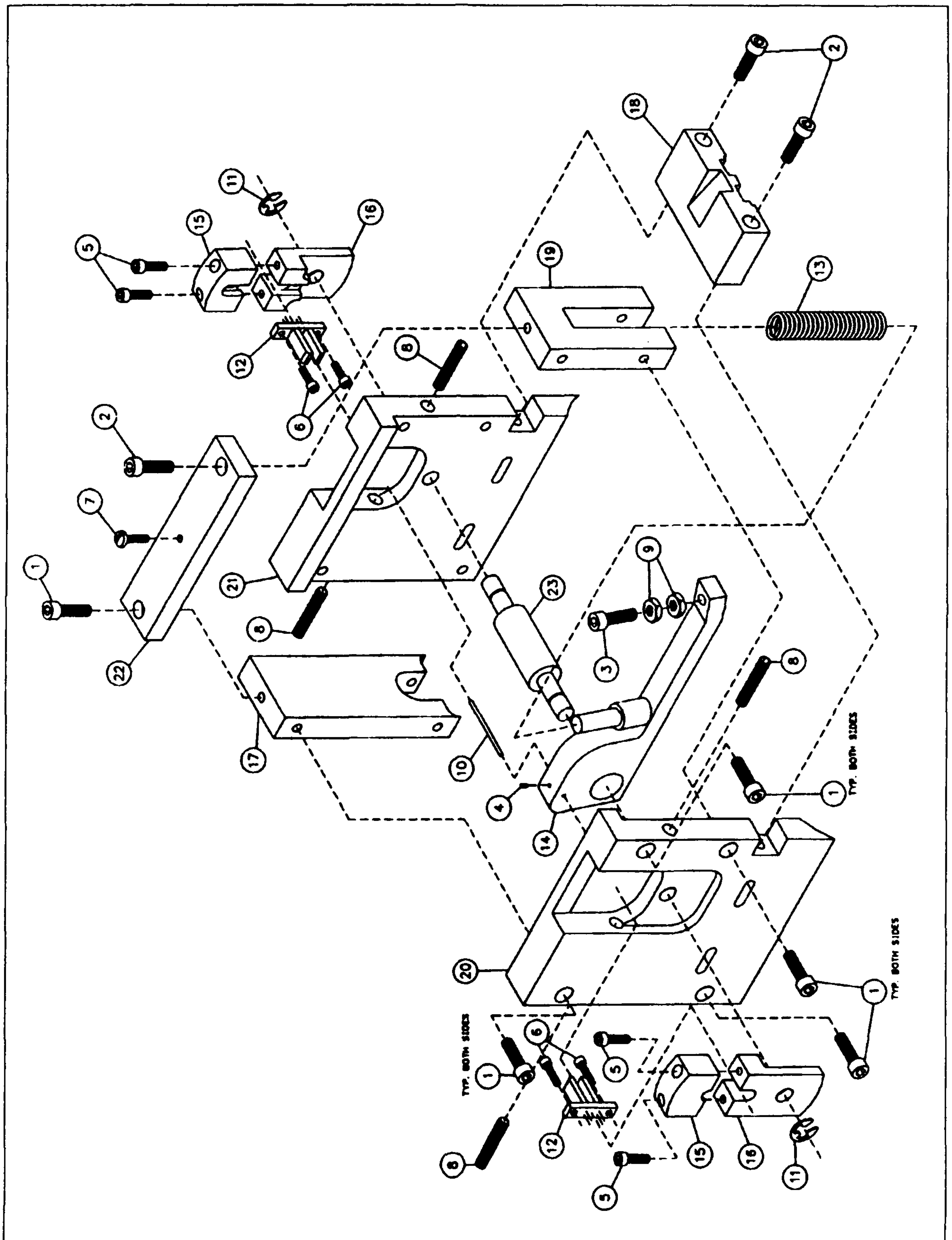

Figure A-8, Motion Sensor Block Diagram, Sheet 8

Motion Sensor Block (continued):

The following is a list of parts for the Motion Sensor Block Mount shown in Figure A-8. For drawings, please refer to the referenced Figures.

Key	Nomenclature	Description	Quantity	Figure
1	Screw, socket head	10-32 X 5/16"	9	
2	Screw, socket head	10-32 X1"	3	
3	Screw, socket head	1/4-24 X 1"	1	
4	Screw, socket head	4-40 X 1/4"	1	
5	Screw, socket head	6-32 X 3/4"	4	
6	Screw, socket head	4-40 X 5/16"	9	
7	Screw, slot head	6-32 X 3/8"	1	
8	Screw, set, socket head	5/16-24 X1"	4	
9	Nut, hex	1/4-24	2	
10	Deactivation pin		1	A-5
11	Retainer		2	
12	Switch, optical	NTE 3100	2	
13	Spring, compression	15/16 X 1/4"	1	
14	Deactivation arm			A-5
15	Retainer plate top			A-13
16	Retainer plate bottom			A-13
17	Rear plate			A-4
18	Arm stop plate			A-4
19	Front plate			A-3
20	Right side plate			A-2

Motion Sensor Block (continued):

Key	Nomenclature	Description	Quantity	Figure
21	Left side plate			A-1
22	Top plate			A-3
23	Pivot rod			A-6

A-6. Signal Convertor (Figure 2-9):

Quantity	Nomenclature	Description
2	Capacitor, electrolytic	0.1-UF, 25-Vdc
1	Battery	Power Sonic, 12-V, 1.9-amp hour, PS1219
5	Connector, non-insulated	BNC Jack, bulkhead mount
4	Connector	MS3112E-8-4P
1	Connector	MS3112E-8-4S
1	Chasis box	Bud, CU-247
2	IC	74HCT04
4	Resistor	100-ohm, 1/4-W
4	Resistor	3300-ohm, 1/4-W
1	Switch, toggle	DPST MS75029-23
1	Vector board	1-1/2 inch x 2-inch
1	Voltage regulator	+5-V, 3-terminal, 7805 (LM340T05)
As needed	Wire wrap Wire IC sockets	No. 30 22 AWG

A-5. Launcher Circuit (Figure 2-10):

Quantity	Nomenclature	Description
2	Connector	BNC jack, KC-79-106
1	Resistor	Precision, 1.2-ohm, 2-W, (1% tolerance)

A-8. Miscellaneous Materials:

Quantity	Nomenclature	Description
1	Chassis	Bud, metal case, SC-13101
1	Power cable	Input power cable, HP type
As needed	Coax cable	RG58
	Coax connectors	For RG58 coax cable
	Sealant	RTV
	Screws	
	Washers	
	Nuts	
	Standoffs	
	Lettering	
	Plexiglass	

APPENDIX B: CONTROLS DESCRIPTION

A description of the Rocket First Motion Timing System (RFMTS) Integrated Time Counter and Firing Unit (Firing Control Box) controls are described below.

B-1. Cabinet (left side):

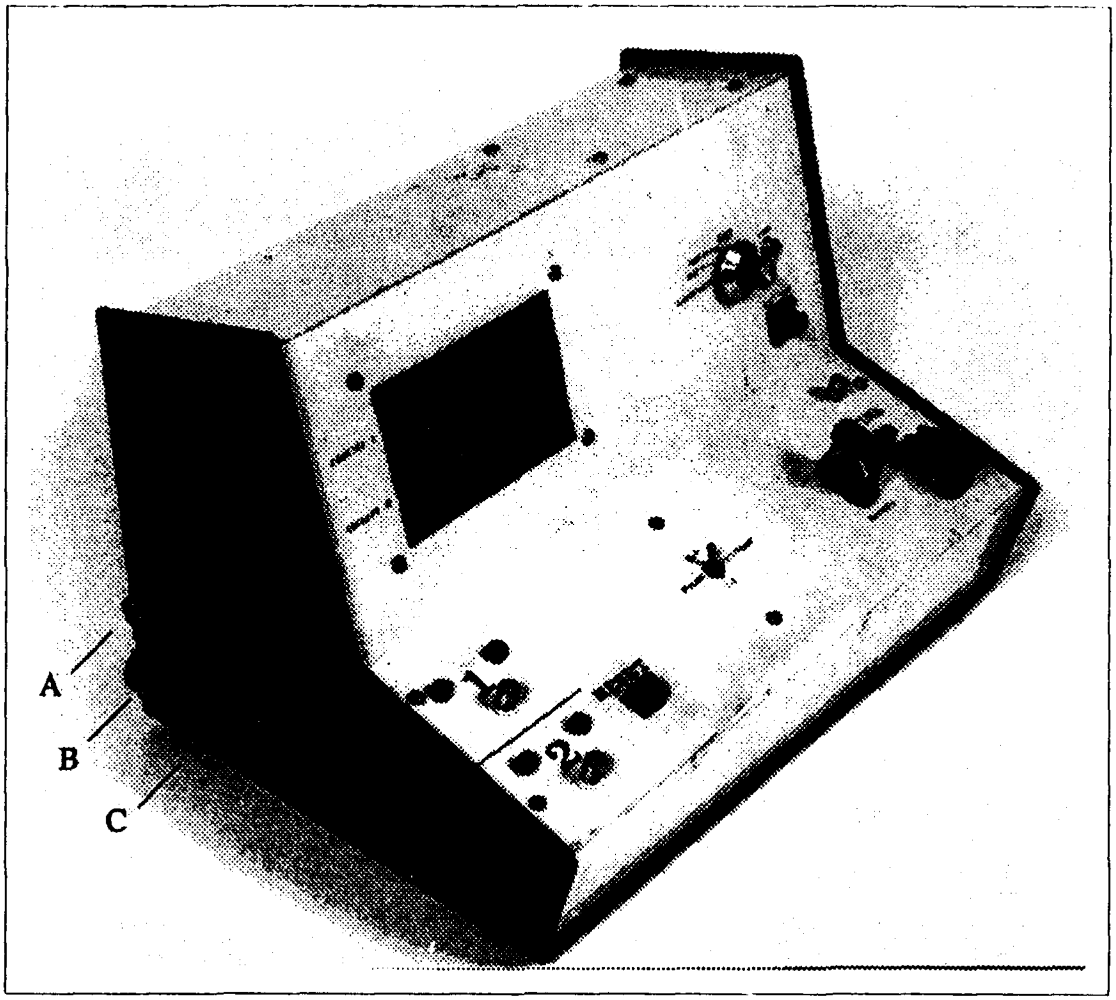

Figure B-1, Firing Control Box (left side)

Key	Control/Indicator	Function
A	Fuse	Protects the battery charger circuits from damage due to circuit overloads.
B	Power Switch S1	Controls ac and dc power to internal circuits.
	OFF	Ac and dc power to internal circuits is disconnected.

Cabinet(continued):

	ON	Dc power is applied to the fire pulse and counter circuits.
	CHG	Ac power is applied to the battery charger; ac power is disconnected from the fire pulse and counter circuits.
C	Ac Input Jack	Connects 115 Vac to the firing unit when battery recharging is necessary. No ac input is required to operate the firing system.

B-2. Upper Front Console:

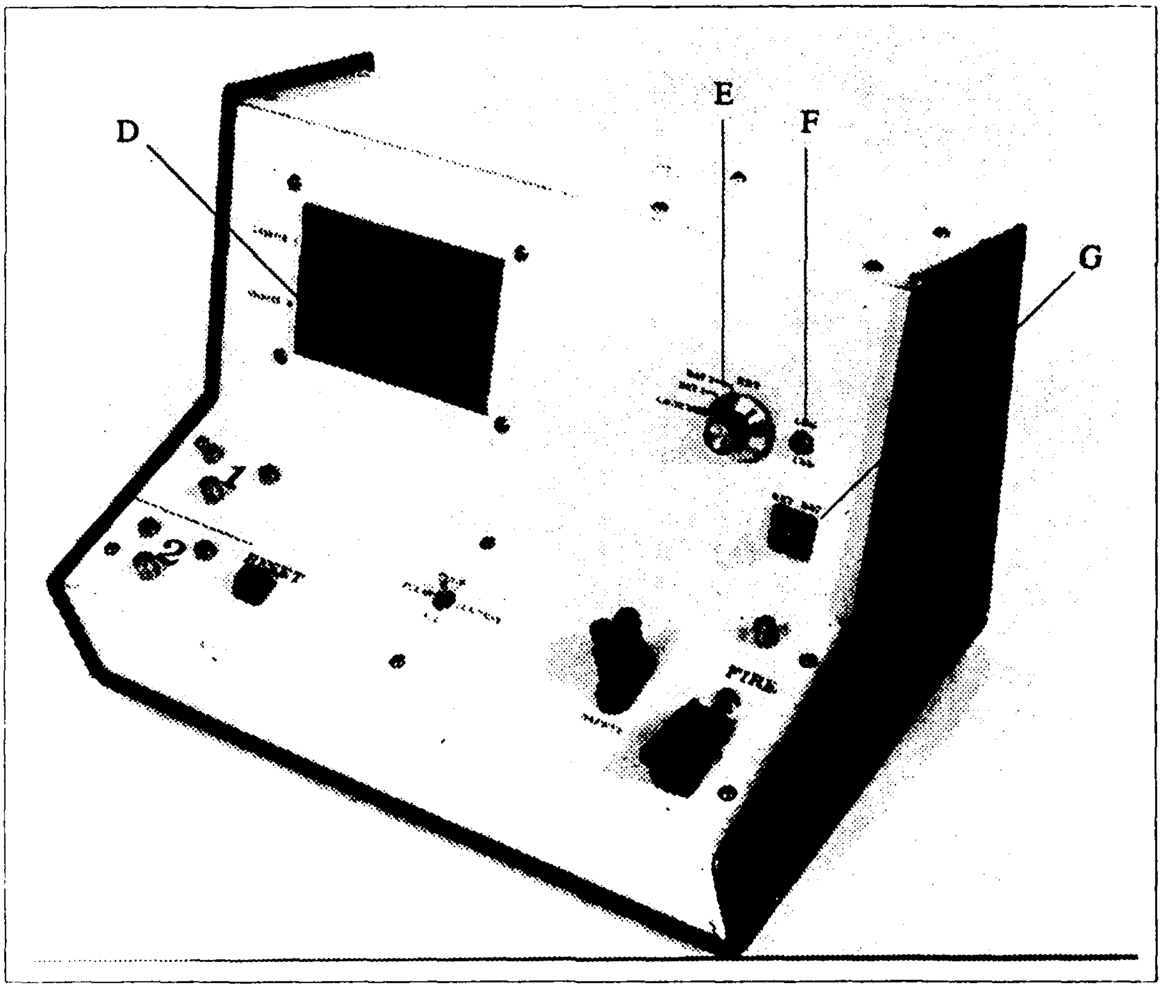

Figure B-2, Firing Control Box (upper console)

Upper Front Console (continued):

Key	Control/Indicator	Function
D	Displays	Indicates time to first motion from 00.0000 to 99.9999 seconds.
E	Mode Switch S2	Places the system in operational or battery-charger mode.
	LAUNCHER	Places the system in operational mode. Rocket firing can be initiated.
	BAT 1	Allows recharging of internal battery #1. Firing mode is disabled
	BAT 2	Allows recharging of internal batteries #2 and #3. Firing mode is not disabled.
	EXT	Allows recharging of external batteries. Firing mode is disabled.
F	CHG IND (Yellow)	Light emitting diode (LED) indicates the status of the battery being charged.
	(illuminated)	Battery is charged to correct voltage or no battery is connected to the charging circuit.
	(extinguished)	Battery charger is off or battery being charged is not at correct voltage.
G	EXT BAT	Connection of adapter cable to allow charging of an exterior battery.

B-3. Lower Front Console:

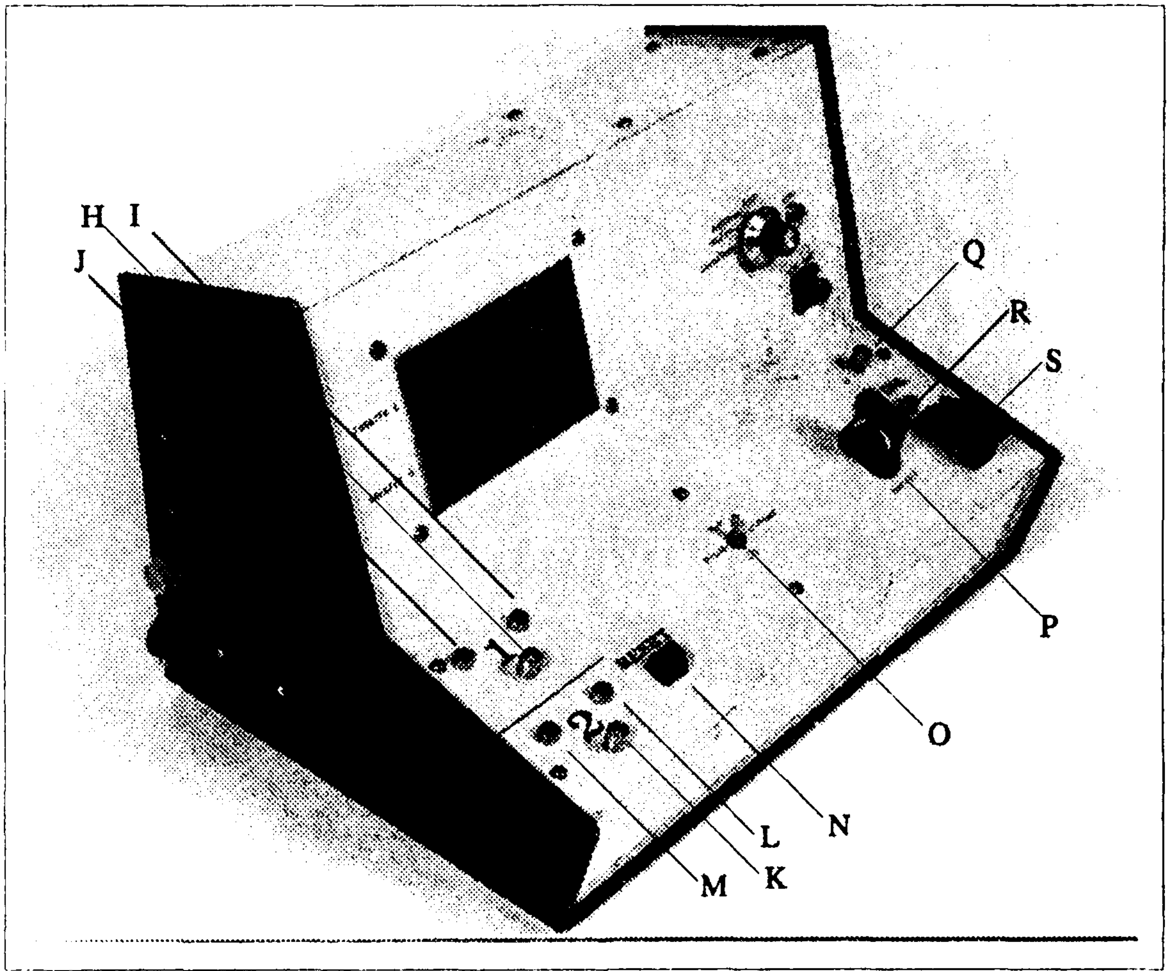

Figure B-3, Firing Control Box (lower console)

Key	Control/Indicator	Function
H	Input Jack	Data connection from (Sensor #1) signal converter to counter circuit.
I	Red LED	When illuminated, indicates counter circuit #1 has been activated.
J	Green LED	When illuminated, counter #1 is ready to accept START and STOP pulses.
K	Input Jack	Data connection from (Sensor #2) signal converter to counter circuit.
L	Red LED	When illuminated, indicates counter circuit #2 has been activated.

Lower Front Console (continued):

Key	Control/Indicator	Function
M	Green LED	When illuminated, counter #2 is ready to accept START and STOP pulses.
N	RESET Switch	Resets both counters and resets time displays to 00.0000.
O	Pulse Current Switch	Selects a firing current regulation level of 1.5 or 3.0 amps.
P	Safety Jumper	Prevents accidental firing of rocket motor when jumper is removed.
Q	Fire Pulse Output	Connects firing pulse connector regulator circuit to safety circuit and rocket launcher.
R	Fire Indicator (LED)	Illuminated red when the FIRE switch is activated and firing current is available.
S	FIRE Switch	Initializes the firing pulse and counter circuits.

APPENDIX C: INSTRUMENTATION ALIGNMENT PROCEDURES

C-1. Battery Charger/Power Supply Alignment Determination

Purpose: The purpose of the following procedures is to determine if adjustment of the battery charger/power supply unit is required.

1. Ensure ac power is connected to firing unit and switch S1 is in the OFF (center) position.

2. Connect external battery charging adapter cable to the external charger connector on front panel of firing unit.

3. Connect a 4.7K-ohm resistor across cable leads.

4. Being careful to observe polarity, connect voltmeter across 4.7K-ohm resistor.

5. Ensure rotary switch S2 is in the EXT position.

6. Turn switch S1 to the charge (down) position. Observe voltage indication of +13.5 ± 0.2 Vdc and CHG IND LED is illuminated.

7. Place switch S1 to OFF and disconnect resistor from cable.

8. Being careful to observe polarity, connect partially-discharged battery to cable and ensure voltmeter is connected across battery terminals.

9. Turn S1 to the charge (down) position and observe that the LED is not illuminated. If the LED is lighted the battery will have to be further discharged. When ac power is turned on and the LED remains extinguished, proceed to the next step.

   NOTE: Power will have to remain off for a minimum of three (3) seconds to allow an SCR Q2 to reset.

10. Observe the LED and voltmeter. The LED should be illuminated when voltmeter indication reaches +13.5 ±0.2 Vdc. If the LED illuminates before +13.3 Vdc or fails to illuminate before +13.7 Vdc, alignment of the charging circuit is necessary.

    NOTE: The voltage indication will start to drop once the LED is illuminated.

11. Turn power off and disconnect adapter cables from firing unit.

12. Disconnect battery and voltmeter from adapter cables.

C-2. Battery Charger/Power Supply Alignment

Purpose: The purpose of these alignments/adjustments is to set the battery charge voltage (Vcc) and to set the current to voltage shift (Q2 gates on) of the charging circuit.

1. Ensure all power to the firing unit is removed and switch S1 is in the OFF (center) position.

2. Using a Phillips screwdriver, remove four (4) screws securing rear access panel; remove panel.

3. Connect external battery charging adapter cables to the EXT BAT connector.

4. Using jumper wires (clip leads), connect a 4.7K-ohm resistor between the adapter cable leads.

5. Connect a voltmeter across the 4.7K-ohm resistor, being careful to observe the polarity of the meter leads.

6. Ensure the rotary switch S2 is in the EXT position.

7. Connect ac power to the firing unit and place S1 in the CHARGE (down) position. Observe voltmeter for a (Vcc) indication of +13.5 ±0.2 Vdc, and also that the CHG IND LED is illuminated.

   a. If all indications are normal, proceed to Step 10.

   b. If LED is not illuminated, proceed to Step 8.

   c. If LED is illuminated but voltage is out of tolerance, proceed to Step 9.

8. Using a small slot-tip screwdriver, slowly adjust R8 until the LED is illuminated. If adjustment of R8 will not cause the LED to illuminate, the LED and/or SCR Q2 may be defective.

9. Using a small slot-tip screwdriver, adjust R3 for a Vcc voltmeter indication of +13.5±0.2 Vdc.

10. Place switch S1 to the OFF (center) position.

11. Disconnect the resistor and multimeter from adapter cable leads.

12. Being careful to observe polarity, connect the adapter cable leads to an external battery and connect the voltmeter across the battery terminals.

NOTE: In order to set or check the current to voltage shift point, the battery will have to be partially discharged. A voltage indication of less than +12.5 Vdc is usually sufficient. If the battery is not sufficiently discharged, Vcc may be reached before final adjustment of R8 can be accomplished.

13. While observing the CHG IND LED, place switch S1 to the CHARGE (down) position. If the LED is still illuminated, discharge the battery further and try again. Repeat this step until the LED remains extinguished when power is applied.

    NOTE: If LED illuminates, power will have to remain off for a minimum of three (3) seconds in order for SCR Q2 to reset.

14. Observe the CHG IND LED and voltmeter. The LED should illuminate just after Vcc is indicated on the voltmeter. If LED illuminates before +13.3 is reached or remains extinguished when voltage goes above +13.7 Vdc, R8 will need to be adjusted. Adjust R8 accordingly. Step 13 will have to be repeated subsequent to each R8 adjustment. This step will have to be repeated several times to ensure proper adjustment.

    NOTE: When Vcc is reached and the LED illuminates, the voltage indication on the voltmeter will begin to drop. This drop is due to the charging status changing from a current rate of approximately 240 mA to approximately 15 mA. The lower rate of charge will continue until power is removed.

15. Place S1 to the OFF position and disconnect power to the firing unit.

16. If no further alignments are to be performed replace rear access panel and secure with four (4) screws.

C-3. Firing Pulse Generator Alignments

Purpose: The purpose of this alignment is to set the firing pulse current within the limits specified by NOS 504-174-TD-006A.

1. Connect test equipment to firing unit as shown in Figure C-1. Ensure that the safety jumper is inserted.

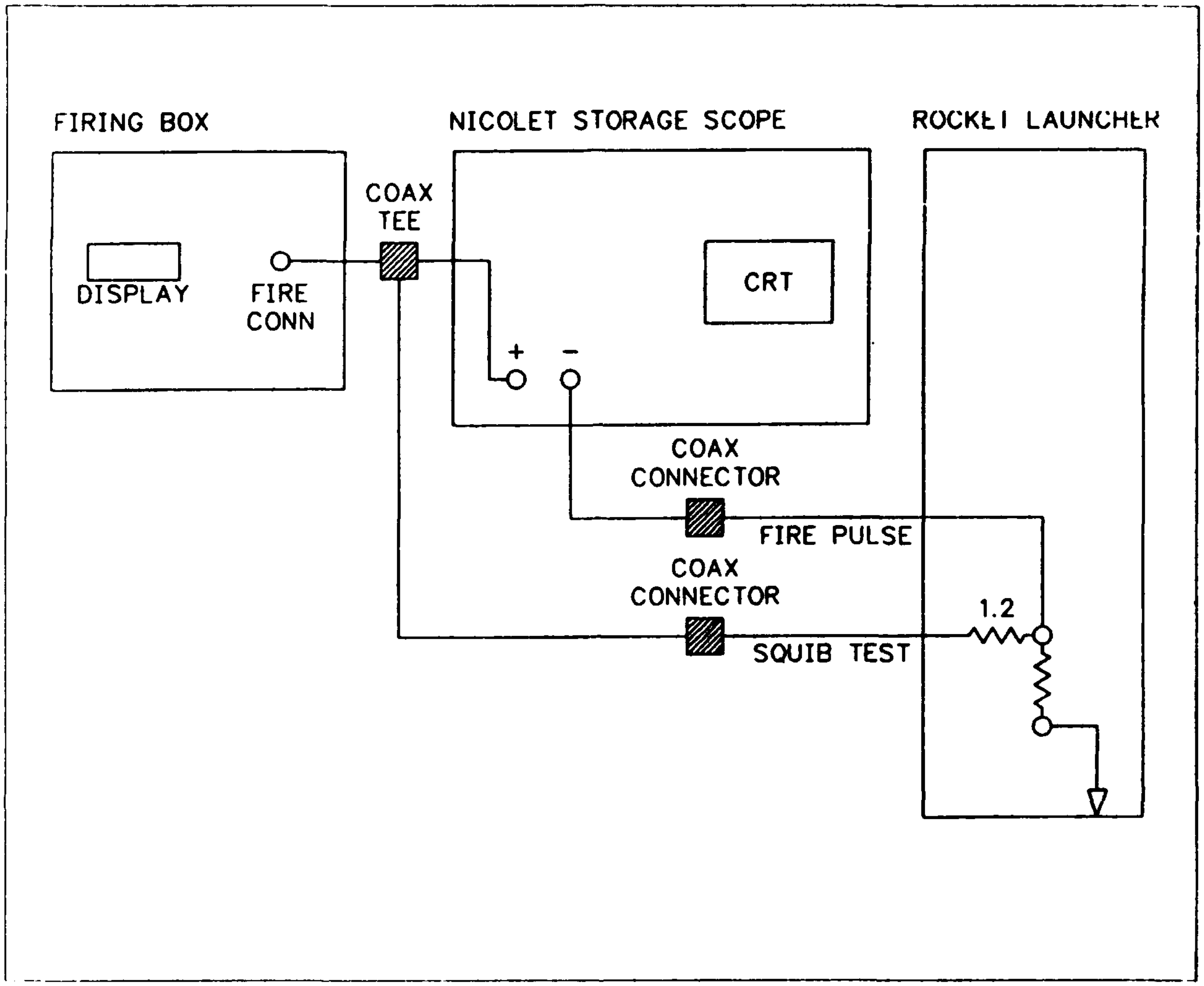

Figure C-1, Firing Unit Connection Schematic

2. Set up test equipment (oscilloscope) to view a pulse 10 V in amplitude and approximately 150-ms duration.

3. On the front of the firing unit:

   a. Place switch S2 to the LAUNCHER position.

   b. Place the PULSE CURRENT switch to 1.5 (down) position.

   c. Ensure that the SAFETY jumper is inserted.

4. Place switch S1 (on the left side of the firing unit) to the ON (up) position.

5. Depress the RESET switch on the front of the firing unit. The counters should indicate 00.0000 and both of the green LEDs should be illuminated.

6. Raise guard from FIRE switch and very quickly depress and release the switch. View pulse waveform on oscilloscope. Pulse duration is dependent on amount of time FIRE switch was depressed. Observe and record the pulse amplitude.

   a. If pulse amplitude is within the +1.8 V and +1.98 V, proceed to Step 12.

   b. If pulse amplitude is not within +1.8 V and +1.98 V, go to Step 7.

7. Using Phillips screwdriver, remove four (4) screws securing rear access panel. Remove access panel.

8. Locate current ADJ potentiometer (located to the right of the batteries) and loosen the potentiometer jamnut.

9. Adjust the potentiometer as necessary to bring pulse amplitude within limits recorded in Step 3. Step 5 will need to be performed each time an adjustment to the current ADJ potentiometer has been made.

   NOTE: If the waveform does not appear as a squarewave and/or the adjustment of the potentiometer has very little or no effect on the pulse amplitude, check VR1 and VR2.

10. Tighten the jamnut on current ADJ potentiometer.

11. Place the PULSE CURRENT switch on the front of the firing box to the 3.0 (up) position. Raise the guard from the firing switch and momentarily depress and release the switch. View the pulse waveform on the storage scope. Ensure a pulse amplitude of +3.36 V to +3.84 V.

    NOTE: The current ADJ potentiometer affects the 3.0 pulse amplitude. If the pulse is not within the values given, place PULSE CURRENT switch to 1.5 position and repeat Step 6 as necessary.

12. Turn switch S1 to OFF (center) position and disconnect test equipment.

13. Secure the firing unit. If the access panel was removed, replace it and secure with four (4) screws.

C-4. Sensor/Launcher Assembly Alignments

Purpose: The purpose of these alignment procedures is to set the optical switches to activate simultaneously at the precise moment that the rocket begins forward motion.

1. Connect the rocket launcher, firing unit, and signal converter together as shown in Figure C-2.

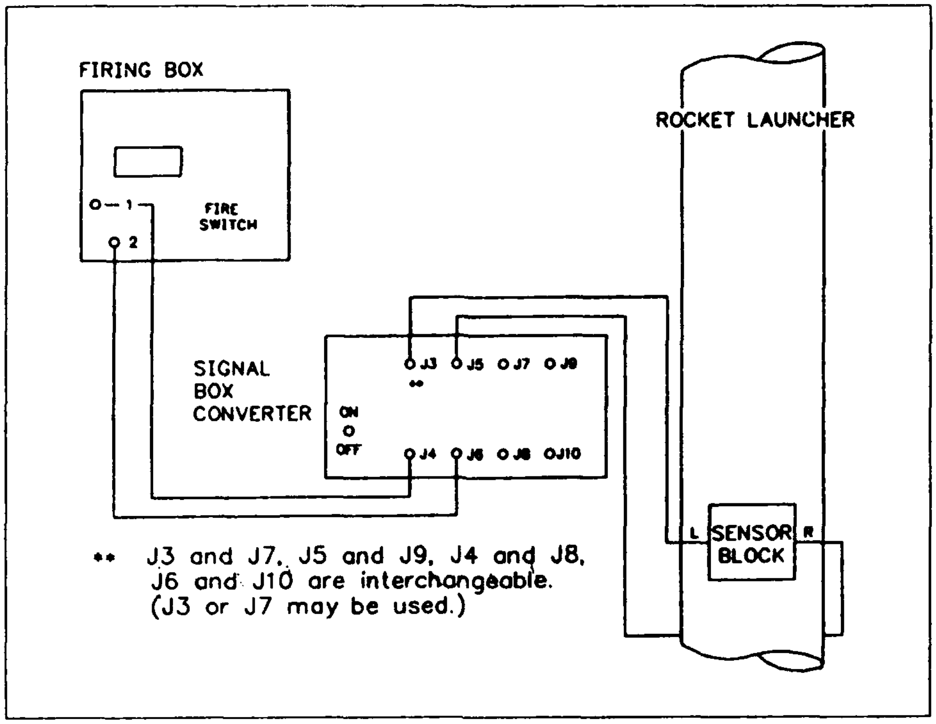

Figure C-2, Optical Switch Synchronization Setup

2. Ensure that the safety jumper has been removed from firing unit and no rocket is located in first motion launcher.

3. Place MODE switch S2 on the firing unit to the LAUNCHER position.

4. Place POWER switch S1 on firing unit to ON (up) position.

5. Depress RESET switch. Observe that both counters indicate 00.0000 and both status input green LEDs are illuminated.

6. On firing unit, raise switch guard from FIRE switch and momentarily depress switch. Observe that both counters are advancing (counting). DO NOT reset counters at this time. Leave FIRE switch guard raised.

7. Place power switch on signal converter to ON (up) position. If the switch was already in the ON position, cycle the switch to the OFF position and then back to the ON position.

8. Observe that both counters on firing unit have stopped within 0.1 ms of each other, and both status input red LEDs are illuminated.

9. Depress the RESET switch on firing unit. Observe both counters indicate 00.0000 and both status input green LEDs are illuminated.

10. Depress the FIRE switch on firing unit.

11. On the launcher, very quickly lift and release the actuator tang. Observe and record counter readings.

    NOTE 1: Counters 1 and 2 should indicate readings within 5.0 ms of each other to be within locally established limits. However, it should be noted that a counter difference reading below 0.5 ms has been consistently maintained.

    NOTE 2: When adjusting for switch synchronization, one or both switches may be adjusted. It is suggested that one switch (SWITCH A) be adjusted for the best mechanical positioning of the switches and actuator tang, and be used as the reference. The other switch (SWITCH B) should then be adjusted to Switch A for final synchronization.

12. Establish and record which switch and its respective counter will become the reference (SWITCH A).

    NOTE: Switch adjusment is accomplished by loosening either the front or the back set-screw, then tightening the opposite set-screw. Moving the switch toward the tang will cause the switch to be activated, causing its respective counter to stop earlier.

13. Adjust SWITCH B set-screws to cause its respective counter to stop at the same time as the counter for SWITCH A. This step may have to be repeated several times.

    NOTE: Steps 8, 9 and 10 will have to be repeated after each adjustment of the switches.

    EXAMPLE:

    SWITCH A/Counter 1 = 08.4516 seconds
    SWITCH B/Counter 2 = 08.4592 seconds

    Compared to SWITCH A, SWITCH B is late and needs to be adjusted toward the tang.

C-5. First Motion Tang Actuator (tang) Adjustment Procedures

Purpose: The purpose of the following procedures is to ensure that the counter stop pulses are generated at the exact moment that the rocket begins forward motion in the launcher.

Procedures: The following procedures set the actuation time of the optical switches in relation to forward movement of the rocket.

1. Ensure that optical switch synchronization is within prescribed limits. (Refer to Sensor/Launcher Assembly Alignment, section D.)

2. Ensure that sensor assembly mounting clamps are tight and tang is aligned on the launcher detent retainer. Tang adjustment screw should contact the detent retainer approximately one (1) inch from the hook end. Please refer to Figure C-3.

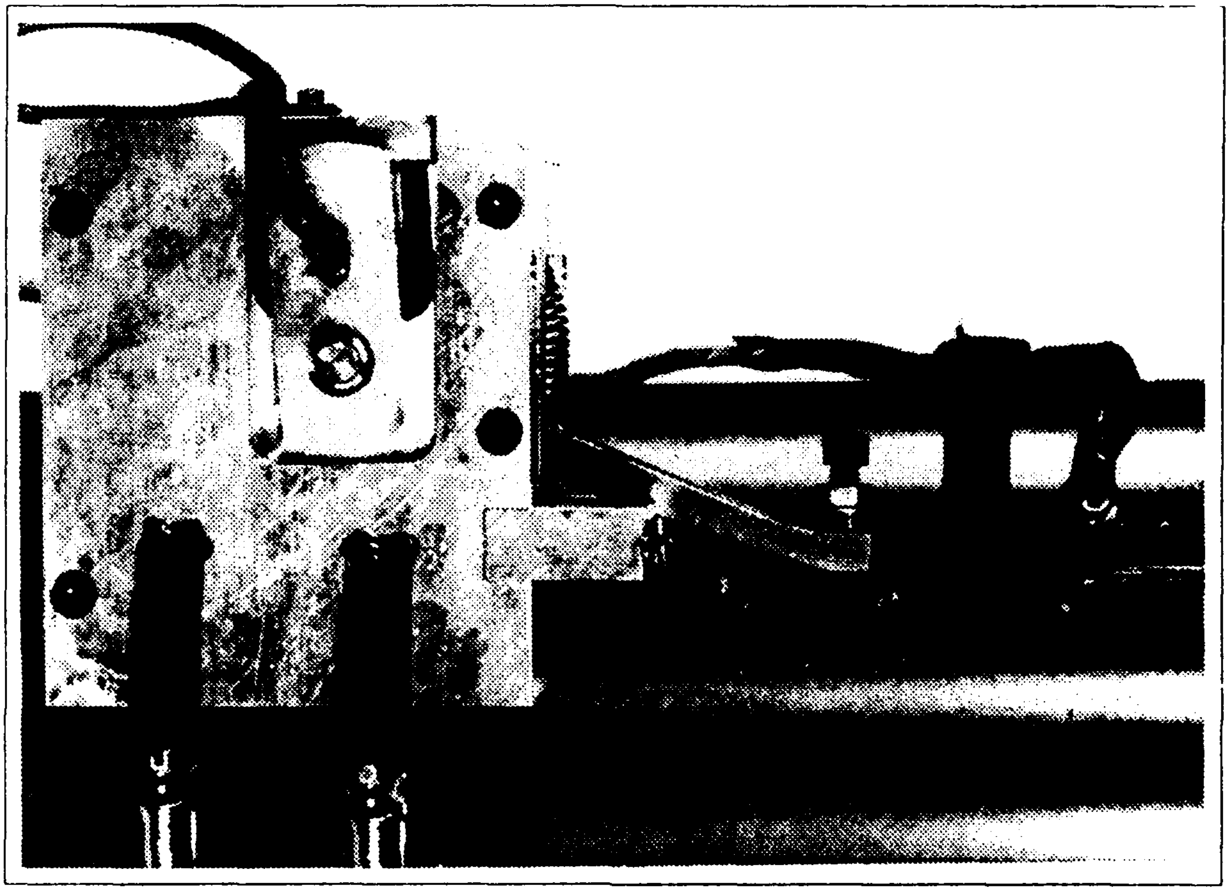

Figure C-3, Tang Adjustment Reference

CAUTION: Do not over-tighten mounting clamps, as warping of the launcher tube will result.

3. Insert an inert MARK 40 or MARK 66 rocket motor into the launcher until the detent retainer is resting on the rocket motor detent shoulder.

4. At the actuator tang, loosen jamnuts and turn adjusting screw counter-clockwise until at least one of the status input green LEDs will remain illuminated when the RESET switch is depressed and then released.
5. At the actuator tang, very slowly turn the adjusting screw clockwise until both status input red LEDs remain illuminated when the RESET switch is depressed and released.

6. Being careful that the detent retainer remains on the rocket detent shoulder, slowly rotate the rocket motor approximately 90 degrees. Perform STEP 5 as necessary. Repeat this step until the rocket motor has been rotated one full turn (360 degrees).

7. At the actuator tang turn the adjusting screw 1/4 turn further clockwise and tighten jamnuts.

8. Reposition rocket motor so that the detent retainer drops into the rocket detent notch.

9. On the firing unit, depress and release RESET switch. Observe that both status input green LEDs are illuminated.

10. Remove inert rocket motor from launcher tube. Observe that both status input red LEDs are illuminated.

11. Turn power off at firing unit and signal converter.

12. Disconnect all equipment and return system to operational status. Recharge batteries if necessary.

APPENDIX D: INSTALLATION AND OPERATING PROCEDURES

D-1. System Installation

1. Connect the firing unit, signal converter, sensor block and safety switch to the launcher as shown in Figure D-1.

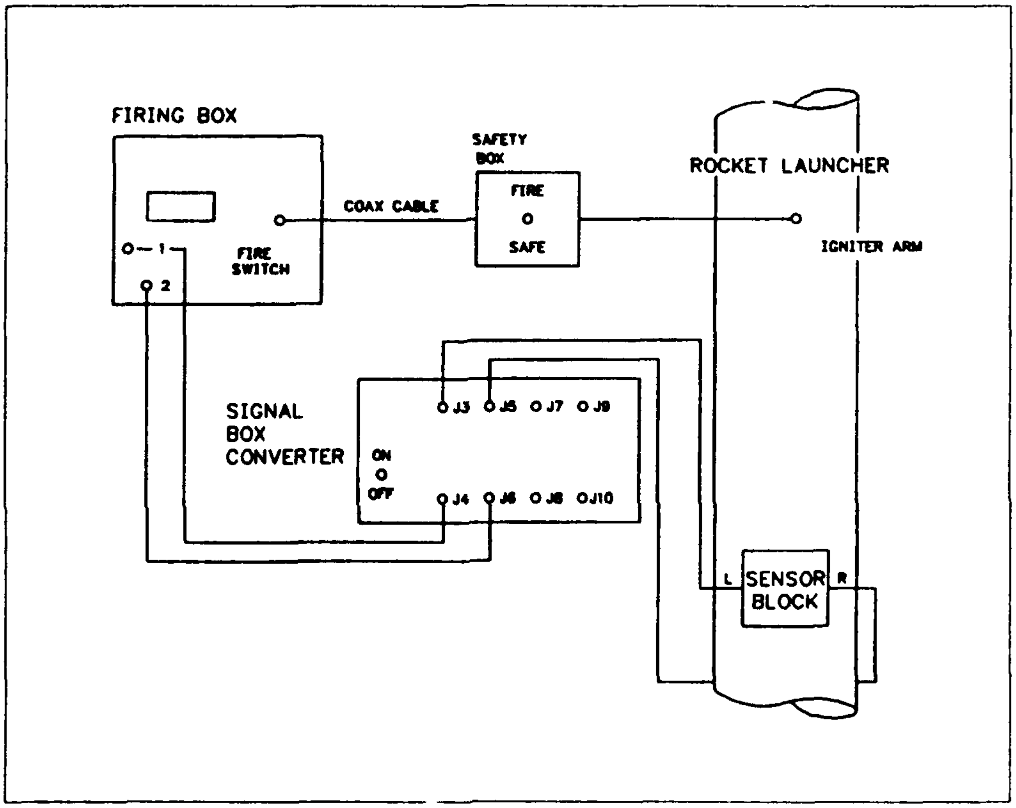

Figure D-1, RFMTS Integrated Unit Connections

2. Activate the POWER by placing switch S1 to the on (up) position.
3. Rotate the MODE switch S2 fully counterclockwise to the LAUNCHER position.
4. Set the PULSE CURRENT switch as required by the test criteria.
5. On the signal converter box, turn the POWER switch to the ON (up) position.
6. Depress the RESET switch.
7. Ensure that both counters are indicating 00.0000.
8. Ensure that both green status LEDs are illuminated.

D-1. Operational Procedures

1. Perform the installation procedures listed in Section A above.

2. Observe all firing range and safety SOPs.

3. Place safety jumper (banana) plug into the safety connector.

4. Initiate a firing pulse by first raising the switch safety guard on the safety box and on the firing unit; actuate and hold the safety switch in the FIRE position and actuate the FIRE switch on the front of the firing unit.

5. Place both switch guards in the down position and remove the safety jumper.

6. Time to first motion will be shown on the firing box counters; both red status indicators must be illuminated.

APPENDIX E: HISTORY OF INSTRUMENTATION DEVELOPMENT

E-1. Introduction:

The report contained in this appendix reveals the history of the instrumentation development for the RFMTS.

The chronological history of the developmental phases for the sensor devices, time counter and firing control box, and the launcher and tubes is addressed in sections E-2 through E-4 respectively. Please refer to section E-5 for pertinent miscellaneous observations.

E-2. Sensor Devices:

During initial stages of instrumentation development, several types of sensors were employed. The first sensor was a Styrofoam cup inserted into the launcher tube just forward of the rocket. Two copper wires were run across the bottom of the cup at intersecting angles, but not touching. As the rocket thrust built up to the point that first motion was reached, the nose of the rocket pressed the bare wires together to make contact, which caused the time counter to stop. This method was too slow and labor intensive; each cup had to be wired, then loaded in the launcher tube for each round.

The second method attempted was the use of 350-ohm and 1000-ohm strain gages which were attached to the launcher detent. This method also proved unsatisfactory; the bonding materials and the strain gages failed due to the extreme heat and pressure from the rocket blast.

The third and final method employed was using and comparing several different types of switches. These switches included roller-/lever-actuated miniature switches, proximity switches, Hall-effect switches, optical switches and straight-lever standard switches.

In all cases during the early development process, two different types of switches were used simultaneously for each firing. The straight-lever standard switch was used as a timing reference and was tested in tandem with the other types of switching devices throughout this third method phase of RFMTS development. The switches were mounted on a fixture and positioned variously to the front of or in back of the detent opening in the rocket tube.

At first, the use of two straight-lever standard switches appeared to work well. They were both installed near the detent; one switch at the front and one at the rear. However, while the rear switch continued to function correctly, the front switch did not. The pre-loaded condition of the actuator arm (lever) in the switch would cause premature actuation due to rocket motor vibration. The switch at the back of the rocket was not pre-loaded but the lever constantly needed adjustment. The lever appeared to be bending by the pressure exerted on it; high-speed film cameras were used to confirm that the lever was indeed bending from both heat and stress.

A Hall-effect switch was next employed; it was installed at the front of the detent. It did not function properly in the extreme heat generated by the rocket blast.

Next, two types of optical switches (translucent and non-translucent) were tested. The optical switches were positioned on the detent, which had been modified to accept the switches. Both types of these switches had functional problems caused by sunlight as well as the heat and debris generated by the rocket blast. Attempts were made to keep debris and smoke away from the optical switch area by using an air compressor to blow air across it; this configuration decreased the failure rate, but the translucent switches were sensitive to ambient light and the non-translucent type would not function properly in direct sunlight. Both types of switches began to fail between 40 to 50 rounds.

A proximity switch in combination with a miniature switch was tried next. The proximity switches worked well in the original mounting fixture, but the configuration did not provide a suitable method for adjustment; therefore a different switch holder was designed. In the final sensor block fixture design, the two proximity switches were threaded into an aluminum housing. The housing did not dissipate heat fast enough; this caused the switches to fail after approximately 18 rounds with a firing rate of approximately 1 round per minute.

In fact, all of the mechanical switches used seemed to fail due to mechanical hysteresis.

The sensor block was moved from the rear of the firing tube to a position just forward of the detent opening. At that time, the alligator clip firing connector was also replaced with a clip/cutter bracket which attaches directly to the igniter arm.

Finally, non-translucent optical switches were mounted to small aluminum blocks and re-tested with the final design of the sensor block fixture. In this configuration, the problems encountered earlier did not recur, because:

a. The switches are internal to the sensor block fixture (which protects them from the rocket blast and direct sunlight);

b. The switches are thermally insulated from the sensor block; and

c. The final sensor block positioning protects it from blasts eminating from the detent opening.

The aluminum block-mounted sensors allowed the operator to make adjustments for switch synchronization and allow for the differences in diameter of the MARK 40 and MARK 66 rockets. During actual firing of the MARK 66 and MARK 40 rockets, it was noted that the diameter difference between the rockets did not necessitate any adjustment to the sensors. There was no noticeable difference between adjusting and not adjusting the detent for each type of rocket.

E-3. Integrated Time Counter/Firing Control Box:

The original system used a STD-BUS CP/M computer with a time interval card designed at YPG. This worked satisfactorily.

A separate 28-V firing box was also designed. The firing box would start the time interval card. This card would record the time until the detent lever reached a level high enough to activate the switch, stopping the time. The first motion times were displayed on the CPU CRT; hard copies were available through the use of a dot-matrix printer.

The second time this system was used, 100% of the firing data was collected. However, the Project Engineer (PE) wanted a simpler, more durable, integrated system. Therefore, a system was designed with a "display only" counter. A new firing box was developed which incorporated two counter displays.

As part of the finalized design of the firing control box, a status light system was also incorporated. Two red lights indicate that the optical sensor switches are in a triggered mode (not ready for firing), and two green lights indicate that the optical sensor switches are in the ready mode (ready for firing). The lights are also used to detect proper seating of the rocket detent when the launcher is being loaded. If a rocket is not properly loaded the system cannot be reset, and the red lights remain illuminated.

After approximately eighteen months of modifications and testing, the prototype design was finalized. During this time, there were a number of rocket motor failures. The rocket manufacturer noted that YPG was experiencing an excessively high failure rate and claimed that too much firing current may have been the cause.

Investigation into the problem revealed that the firing pulse current was not in compliance with NOS 504-174-TD-006A, which states that the fire pulse current during field testing will be 1.5 amps + 10% tolerance. The firing box had been designed to supply +28 Vdc to the rocket squib, with the current limited only by the squib resistance (normally 0.7 to 3.5 ohms).

The firing control box circuitry was modified to deliver the regulated 1.5 amps + 10% as specified in the NOS. The new current-regulated firing control box was used to fire three new acceptance lots; the results showed no rocket failures. Test rockets from the previously failed lots were then fired, with the same high failure rate as before. The conclusion was that the firing box now met the field test specifications, and was not the cause for the excessive failure rate of the three lots of rocket motors.

Circuitry was also designed to ground the firing lead wire until it was engaged. This safety feature prevented a short in the firing box from sending out a firing pulse and also prevented stray voltage from being induced into the firing cable from external sources.

The operating voltage was also changed from 110 Vac to 24 Vdc. The voltage to the launcher was changed from 28 Vdc to 24 Vdc. Circuitry was redesigned to accept a maximum squib resistance of 10 ohms at 1.5 amps or 5 ohms at 3.0 amps firing current. This final firing control box then contained an integrated counter, batteries, battery charger, and the current-regulated firing system.

The final design of the instrumentation is currently used for acceptance testing of HYDRA-70 and ZUNI rocket motors using the M158A1 launcher. Several observations were made pertaining to the launchers/tubes during firing tests.

E-4. Launchers/Tubes:

The M158A1 launcher wiring was modified to incorporate the RFMTS system. The existing launcher wiring was removed and replaced with RG58 coax cable. The firing-pulse cable was designed so that only one tube is connected to the RFMTS at any given time. A second cable is also atached to the same tube in parallel with the firing-pulse cable. A 1.2-ohm precision resistor is connected in series with the firing current when the cable is connected to the firing control box. This cable is used as a squib test line, and is used for alignment purposes only.

The detent release force of 200 pounds of thrust required by NOS 504-174-TD-006A is measured only once during manufacture of the rocket launcher. Measurement is not required again for the life of launcher. Continued use of the launcher may cause the detent to weaken; the force required to overcome the detent release pressure would vary accordingly. This variance in the detent release pressure can effect time to first motion. This detent problem needs to be addressed in order that a more accurate first motion time can be obtained.

The M158A1 launcher was used for this RFMTS testing because all the parts of the launcher are accessible. If the launcher is changed for a newer (enclosed) type, the instrumentation will not work because it would be impossible to mount the sensors.

The usual cause of a launcher failure is a serious dent or bulge in it. Wear of the tube is not measured as part of the inspection process. The actual number of rockets fired from the first RFMTS launcher tube is not known, but a check into available records indicates that more than 10,000 rockets had been fired from it when it was removed for a Magnaflux test; no evidence of stress, cracks or bulges were evident. The tube was reinstalled, then replaced in February 1991. The second tube was replaced in October 1991, and a record of all firings from the new tube is being kept.

E-5. Miscellaneous Observations:

In all rocket launches, the rocket motor wiring becomes shrapnel and is jettisoned out the rear of the launcher. This is detrimental to sensors connected at the rear of the detent opening. The Mark 40 rocket blasts produce more carbon, fire, and debris than the Mark 66; these in turn cause the optical switches to foul more quickly. To reduce fouling, the sensors were moved forward of the detent opening.

Other differences were noted between the Mark 66 and Mark 40. The fin assembly and the firing contactor configuration necessitated the modification of the launcher wiring and fire arm in order to fire the Mark 66.

APPENDIX F: DISTRIBUTION LIST

Commander U.S. Army Test and Evaluation Command AMSTE-TC-D Aberdeen Proving Ground, MD 21005-5055	5
Commander U.S. Army Combat Systems Test Activity AMSTE-RM-PL	1
STECS-DA-ID Attn: Dr. Harley	1
STECS-ENP Attn: Mr. Jones Aberdeen Proving Ground, MD 21005-5059	1
Commander U.S. Army Cold Regions Test Center STECR-TD APO Seattle, WA 98733-7850	1
Commander U.S. Army Tropic Test Center STETC-TD-M APO Miami, FL 34004	1
Commander U.S. Army White Sands Missle Range STEWS-PL-P White Sands Missle Range, NM 88002-5031	1
U.S. Army Tank-Automotive Command AMSTA-QA Attn: Mr. Ron Sturgeon	1
AMCPM-HFM-QR Attn: Mr. David Lewandowski Warren, MI 48090	1
Commander U.S. Army Yuma Proving Ground STEYP-MT-T	13
STEYP-MT-EA Attn: Mr. Charles Ramsdell	1
ASQNC-TYU-IC-TL Attn: Mrs. Jean McCall Yuma, AZ 85364-9102	1

Commander U.S. Army Dugway Proving Ground STEDP-PO-I Dugway, UT 84022-5000	1
Commander U.S. Army Electronic Proving Ground STEEP-MO Fort Huachuca, AZ 85613-7110	1
Commander U.S. Army Jefferson Proving Ground STEJP-TD-M Madison, IN 47250-5100	1
Commander U.S. Army Aviation Development Test Activity STEBG-MP-P Fort Rucker, AL 36362-5276	1
Commander U.S. Army Missile Command AMSMI-LC-HM Attn: Don Kennamer Redstone Arsenal, AL 35898	1
BEI Defense Systems Co. Attn: Mr. Bill Marks 11312 South Pipeline Road Euless, TX 76039	1
Defense Technical Information Center DTIC-DDAC Cameron Station Alexandria, VA 22314	1
Office of the Under Secretary of Defense RE/DDTE Pentagon, Room 3E1060 Washington, DC 20310-0103	1